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ENTOMOLOGICAL SERIES—BULLETIN No. 4

DEPARTMENT OF AGRICULTURE
MYSORE STATE

SOME SCALE INSECT PESTS OF COFFEE IN SOUTH INDIA

LESLIE C. COLEMAN, M.A., PH.D.
Director of Agriculture in Mysore

AND

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Frontispiece

FRONTISPIECE.

[illegible] aves and twig infested with Green Bug (*Coccus*

F[illegible] and twig infested with Brown Bug (*Saissetia* [illegible]*ericum*,)

FIG. 3.—Coffee leaves and twig infested with Mealy Bug (*Pulvinaria psidii*).

FIG. 4.—Coffee leaf showing parasitized Green Bugs.

FIG. 5.—Coffee leaf showing Green Bugs attacked by black fungus (*Empusa lecanii*).

FIG. 6.—Coffee leaf showing Green Bugs attacked by white fungus (*Cephalosporium lecanii*).

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FOREWORD.

This bulletin gives the results of investigations extending over more than four years. While the planning of the work and the carrying out of investigations in the laboratory and insectary have been in the hands of the authors, most of the field work has been conducted by Messrs. B. C. Shantappa and T. V. Subramaniam, Junior Assistant Entomologists. The excellent coloured plates are from paintings made by Mr. Ranganayakalu Naidu, Senior Artist of the Department.

November, 1917. LESLIE C. COLEMAN.

SOME SCALE INSECT PESTS OF COFFEE IN SOUTH INDIA.

INTRODUCTION.

THE Scale Insects or Coccidæ form a large group embracing some of the most serious pests of cultivated plants and at the same time including useful forms such as the cochineal and the lac insects. Text-Fig. 1 shows the external structure of one of these insects and may be taken to represent the group in general. The popular name, scale insects, appropriately describes their scab or scale-like appearance. The shape is usually flat and oval but is often obscured by secretions of a resinous or waxy nature and by ovisacs or egg bags at the hind end of the body. There is usually little or no trace of segmentation, the three natural divisions of the body, *viz.*, the head, the thorax and abdomen running into one another. There are three pairs of legs ending in hooks. The eyes are minute black spots near the margin. The mouth is situated between the first pair of legs. The mouth parts consist of four long slender hairs closely approximated to form a tube, along which the plant sap is drawn. When not in use, this tube is withdrawn into a special sac inside the body where it remains in the form of a loop, the sharp point only appearing outside. For the manipulation of the proboscis there are a number of muscles which converge into a small chitinous cradle (see Plate II, Fig. 3).

The sexes of scale insects are sharply differentiated in the adult stage. The females retain more or less the flat oval shape and are wingless. The males, on the other hand, are provided with a pair of wings and a pair of eyes, but have no feeding apparatus. The reproductive powers of scale insects are enormous. The number of young produced may reach several hundreds and a large number of species reproduce without the assistance of a male. The

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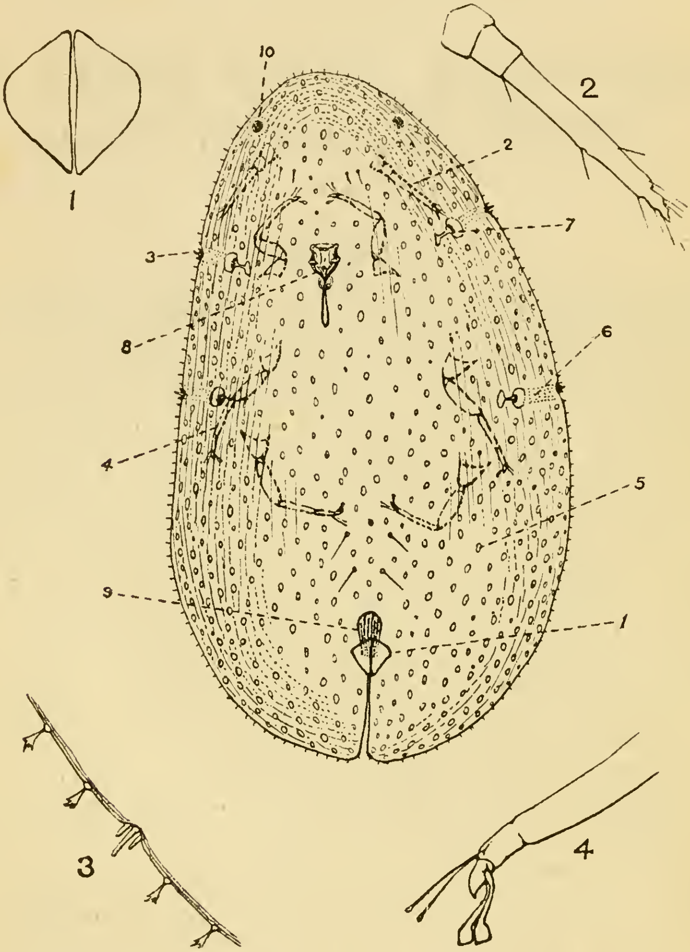
life history is usually short so that there are several generations during the year. With these facilities, the insects multiply rapidly into many thousands. It is easy to imagine therefore that the cumulative effect of such



TEXT-FIGURE 1.—The outline of a scale insect (*Coccus colemani*) is given in the centre, the various structures indicated being as follows:—1. Anal plate. 2. Antenna. 3. Setæ at entrance to stigmatic groove. 4. Leg. 5. Dermal pore. 6. Stigmatic groove. 7. Stigma or breathing pore. 8. Mouth parts. 9. Anal setæ. 10. Eye.
1. Anal plates enlarged. 2. Antenna enlarged. 3. Portion of margin enlarged showing setæ. 4. Foot enlarged.

rapidly increasing numbers on a host plant may lead to its rapid weakening or death.

There are a number of scale insects recorded attacking coffee in South India. Mr. Fletcher lists seven in his South Indian Insects. Of these, three, namely, green bug

(*Coccus viridis*, Gr.),[1] brown bug (*Saissetia hemisphæricum*, Targ.) and mealy bug (*Pulvinaria psidii*, Mask.) are often found associated together in Mysore, and planters have some difficulty in distinguishing one from another, more especially in their younger stages.[2] In the adult stage, the green bug is of a pale lemon-green colour and has almost invariably a dark loop on the back (see Plate I, Fig. 1). The shape is a flat oval, but those along the sides of veins show a slight twist to right or left and have the front end more or less sharpened to a point. If an adult bug is lifted from the leaf, a few young and their cast skins are found beneath. The mealy bug, when full grown, secretes a waxy material resembling cotton in appearance which, like a cushion, lifts up the hind end of the body and in which eggs are laid. It shows no black loop on the body and no live young are to be found beneath the mother (see Plate I, Fig. 2). The colour varies considerably with the host plant but those on coffee are usually more yellowish and less transparent than green bug. There is no difficulty in recognising the brown bug in its adult stage. It is of a snuff-brown colour and almost hemispherical in shape (see Plate I, Fig 3). The difficulty in distinguishing one species from another arises when the bugs are in the earlier stages of growth. The young of green and mealy bugs are almost alike and it is only after some experience that one is able to differentiate the two species. The young of the mealy bug are usually a shade deeper green than those of green bug and are more opaque (see Plate I, Figs. 4 and 5). The young brown bugs are either dark pink or completely yellow. When of the former colour, they are easily recognised. When yellow, the shape has to be examined, which is a short instead of an elongated oval. Half-grown specimens can be distinguished by the presence of a branched ridge on the back somewhat resembling an "x" which has been

[1] This insect was originally described by Green as *Lecanium viride*, and by this name it is commonly known. Recent systematic work, however, has led to the splitting up of the genus *Lecanium*. This generic name therefore ceases to exist and the older name *Coccus* takes its place in the case of the green bug. *Vide* M. E. Fernald, Catalogue of the Coccidæ of the World, Hatch Experiment Station Bulletin No. 88.

[2] In the frontispiece, Figs. 1-3 show the appearance of these three pests on coffee leaves and twigs. Plate I, Figs. 1-6, show in more detail the appearance of both young and adults of the three forms.

elongated vertically (see Plate I, Fig. 6). The following table summarises the differences described above:—

	Adult				Young	
	Colour	Secretes meal or not	Produces eggs or young	Shape	Colour	Shape
Green bug	Light lemon-green to greenish yellow	Secretes no meal	Young	Flat oval with usually a slight twist to right or left	Translucent and green	Oval
Mealy bug	Dark green or olive-green to light yellow	Secretes meal	Eggs	Oval without twist and flat	Opaque and greenish-yellow	Oval
Brown bug	Snuff-brown	Secretes no meal	Eggs	Round and hemispherical	Bright yellow or dark pink or both mixed	Short oval, with ridge on back

The Green Bug or Green Scale of Coffee.

Coccus viridis (Green), Fernald, Catalogue of the Coccidæ of the World, p. 174, 1903.

Lecanium viride (Green), Entomologists' Monthly Magazine, 1889; The Coccidæ of Ceylon, p. 199.

Green bug has always been regarded as a most serious enemy of coffee. According to Green,[1] who first described the insect, it was practically responsible for the final abandonment of coffee in Ceylon. Since its appearance in Ceylon in 1882, it has been recorded from almost all the coffee-growing countries of the world. Green does not give the distribution of the pest, though he refers to a new variety described by Mr. Newstead, from Lagos in West Africa. Mrs. Fernald[2] recorded it from Ceylon, Brazil and Mauritius. From scattered references to the pest in the Review of Applied Entomology, it appears to exist either as a pest of lime or coffee in Samoa, East Africa, Seychelles, Virgin Islands, Barabados, Guadaloupe Java, Uganda, South Africa, Hawaii and Mauritius in addition to India and Ceylon.

The insect was not recorded from Ceylon before

[1] Green, Coccidæ of Ceylon, Parts I to IV, p. 199, 1896 to 1909.

[2] Mrs. Fernald, Catalogue of the Coccidæ of the World, p. 174, 1903.

PLATE I

PLATE I.

FIG. 1.—Adult green bug (*Coccus colemani*).

FIG. 2.—Adult mealy bug (*Pulvinaria psidii*).

FIG. 3.—Adult brown bug (*Saissetia hemisphæricum*).

FIG. 4.—Young green bug.

FIG. 5.—Young mealy bug.

FIG 6.—Young brown bug.

FIG. 7.—Green bug showing a pupa of a hymenopterous parasite inside it. To the left and above is to be seen the yellowish larva of a hymenopterous hyper-parasite attached to the pupa.

FIG. 8.—Green bug attacked by white fungus (*Cephalosporium lecanii*).

FIG. 9.—Green bug attacked by black fungus (*Empusa lecanii*).

1882. Nietner does not give it in his List of the Enemies of the Coffee Tree in Ceylon published in 1876. When the pest first attracted attention in 1882, it had already established itself in the Matabele District. Within four years from that date, it had spread over practically the whole of the planting areas in the Island. In 1889, Green wrote, "the green scale has practically wiped out coffee cultivation in many districts. The vigour and the rapidity with which it is propagated has defied any remedial measures that we could afford to apply and consequently planters are everywhere turning their attention to the cultivation of tea in place of coffee."[1]

In the Coccidæ of Ceylon, published in 1904, Green gives a more correct estimate of the share the scale had in the gradual abandonment of coffee cultivation. He says, "unfortunately at the time of the invasion (by the pest) our coffee had been weakened by long continued attacks of leaf disease (*Hemileia vastatrix*). Moreover, the prevailing system of cultivation resulted in the loss of the surface soil so essential to the health of the coffee plant in all but the most favoured situations. The further tax on its strength induced by these myriads of sap-imbibing insects proved too great for the plant, with the result that thousands of acres of coffee land were abandoned or replaced by tea. Some idea of the collapse of the coffee industry may be obtained by comparing the annual export of coffee during the period of attack. In 1881, 452,000 cwts., were shipped from Ceylon. In 1891 this figure had fallen to 88,780 cwts., while during the past year, 1902, the total scarcely exceeded 10,000 cwts."[2]

How the pest first appeared in Ceylon is not definitely known. Green believes that it was brought over on Liberian coffee from East Africa. The only evidence in support of this view, apart of course from the suddenness of its appearance and the rapidity with which it spread over the Island, is, apparently, the testimony of a planter that it was found to thrive better on Liberian coffee. The record of introduced species in their new homes is certainly in favour of the supposition. The introduction of the rabbit into Australia and of the fluted scale (*Icerya purchasi*) into California are well-known

[1] Green, Insect Life, March, 1889; cited from Indian Museum Notes, Vol. 2, p. 113, 1891-93.

[2] Green, Coccidæ of Ceylon, Parts I to IV, 1906 to 1909, p. 199.

instances where the species concerned, having in their new environment none of the checks which hindered their multiplication in their old homes, rapidly grew into formidable pests. In the case of the last-mentioned species, the fluted scale, when its chief natural enemy was introduced into the new country, the pest was rapidly brought under control. In Ceylon itself, Green regards as presumably imported species, most of the more troublesome scale insects. Of ten species given by him, four were known in Europe, four in America and two in Australia before they were recorded from Ceylon.

Although the suddenness of appearance of green bug and its rapid spread over the island is in favour of the view that the insect has been introduced, the causes of the sudden multiplication of insects into pests are so varied and many of them so obscure that a previous record elsewhere or the fact of sudden appearance is not of itself sufficient for establishing a theory of importation.

The Pest in South India.

The appearance of this pest in South India was not long delayed after its appearance in Ceylon. In the first volume of the Indian Museum Notes[1] (1889-91), there is an article which refers to the bug as having "of late years done serious injury to coffee cultivation in Southern India and Ceylon." From the same article it appears that as early as July 1888, experiments towards the control of the pest had already been tried on the Nilgiris. In the Shevaroys the pest first appeared in 1903.[2]

The Pest in Mysore.

The first intimation received by this Department of the outbreak of green bug in the coffee districts of Mysore was in March 1913, when specimens of the scale were sent in for identification from an estate near Saklespur (Hassan District). These were determined as *C. viridis.* Specimens forwarded shortly afterwards from another estate were also found to belong to the same species. In May 1913, half a dozen estates were known

[1] Indian Museum Notes, Vol. I p. 49, 1889-91.
[2] *Vide* Fletcher, Planters' Chronicle, Vol. VIII, 1913, p. 446.

to be infected. The outbreak in Coorg was noticed simultaneously, and in an article in the Planters' Chronicle in June 1913, Anstead noted the fact that the area of infestation in Coorg was greater than that in Mysore.

Sources of Infection in Mysore.—Though the pest broke out in the coffee estates only in 1913, it was in existence in the State at least some years previous to this date. The first reference to the scale in Mysore occurs in the annual report of Dr. Lehmann, the Agricultural Chemist, for the year 1901-02.[1] Specimens of a scale had been received early in the year from an estate near Santaveri. These had been forwarded to Mr. L. de Nicéville, Entomologist to the Government of India, who identified them as *L. viride* (*C. viridis*). This identification was wrong, however, even though in his letter to Dr. Lehmann he went so far as to point out that "the mealy bug appearance of the insect is caused by a white mould and is not secreted by the insect itself." In giving this caution, Mr. L. de Nicéville had evidently in mind the distinction between green bug and the mealy bug. Nevertheless, the identification was wrong for, in Dr. Lehmann's report of the year 1903-04,[2] this pest is referred to as the green mealy scale and not as green bug. In the interval between the two reports, Lefroy, Imperial Entomologist, had visited the estate near Santaveri and identified the pest as *Pulvinaria psidii*. There is practically no doubt that the latter identification was the correct one.

A still later but now correct reference to *L. viride* occurs in the Planters' Chronicle of the 21st December 1912. It had been brought to notice at the annual meeting of the United Planters' Association of Southern India that the gardens of the florists in Bangalore, and possibly the Lal-Bagh also, were infected and that the pest had been introduced into the Mudgere Taluk, in 1911, on one of the orange plants brought from Bangalore. To prevent the Lal-Bagh acting as a distributing centre of the scale, Mr. Anstead addressed the Superintendent on the advisability of establishing a fumigatorium in the Gardens and, in accordance with this suggestion, one was

[1] Lehmann, Report of the Agricultural Chemist for the Year 1901-02, p. 19.

[2] Lehmann, Report of the Agricultural Chemist for the Year 1903-04, p. 29.

established and the fact intimated in a letter by the Superintendent, which was published in the Planters' Chronicle of the date given above. As a matter of fact, the scale had been observed in Bangalore two years before its introduction into Mudgere in 1911. It was taken in the extensions in Bangalore as early as 1909, and it is quite probable that it was in existence here much earlier. Though the infection of the coffee estates may thus, with a fair degree of certainty, be traced to Bangalore, it was believed at the time of the first outbreak that the immediate source of infection was the Indian bottle gourd *Lagenaria vulgaris*, grown in the villages of the "low country".[1] The evidence in support of this theory was the testimony of the coolies, who said they had seen the plant attacked by the scale. It was supposed that the remains of the vegetables purchased from the local market were thrown on the manure heaps from which they were transferred to the estate along with the manure. The fact that a couple of infected estates had emloyed temporary coolies from the "low country" appeared to support the theory.

A second theory was that the bug had been carried on manure bags sent from a firm who have large curing works at Coimbatore to deal with coffee coming, for the most part, from infected estates in the Nilgiris. It was stated that most of the estates supplied with manure by the firm were infected. The firm protested that the manure works and curing yards were a mile apart and pointed out that the estate in which the pest was first noticed had not purchased manure from them at all. The theory now took another form. The pest was not brought over from Coimbatore but along with infected green fodder collected during transit by the cartmen at the halting places *en route*.

The theories that the infestation of coffee estates had occurred from the "low country" either through manure or through fodder were not probable ones. The only observations in support of them were those made by coolies who could certainly not be trusted to recognise correctly the green bug which, as is well known, has a strong resemblance to the mealy bug found all over the State on many garden plants. Both of these theories left unexplained the simultaneous and even wider infection of Coorg

[1] By "low country" is meant the plains of Mysore lying to the East of the coffee area.

where the manure was obtained almost entirely from the West Coast which was not infected. In spite of this improbability, it was decided to make a thorough investigation of suspected sources of infection in Mysore. In the earlier stages of the outbreak when no more than half a dozen estates had been infected, and there was reasonable hope of stamping it out entirely from the infested blocks or patches, it was all-important that the effect of these measures should not be neutralised by allowing the sources of infection to continue. If, as appeared certain, Bangalore was the original source of infection, the possibility was not excluded of the infection of the "low country" from the same source and of this latter acting as a secondary and more immediate centre of distribution of the pest. A thorough inspection was therefore made of all the places (1) where carting of manure begins, (2) where carts halt on their way to coffee estates and (3) from which green fodder is obtained if the supply is exhausted on the way. A list of the scale insects obtained from the places visited will be found in Appendix I. As is clear from the table, no green bug was obtained anywhere; on the other hand, the mealy bug, which is often mistaken for green bug, was found in twenty places. During the writing of this bulletin (July, 1917) green bug has been found in two places in a locality previously inspected. This is probably due to a subsequent infection and does not vitiate the conclusions already reached.

Soon after this exhaustive search for green bug along the roads leading from the "low country" to the estates was over, in October 1913, a thorough inspection was made of the country within a radius of three to four miles of each of the estates known to be infected. The "hitlus"[1] and gardens in nearly ninety villages were gone over carefully but only in five of these was the bug detected. These were close to or adjoining the larger infested estates and were almost certainly infected from them. In nearly all of the five, mealy and brown bugs were also found in more or less abundance.

The investigation of the sources of infection was now stopped. The inspection showed that the scale had spread over too wide an area to render the discovery of

[1] "Hitlus" are small plots of a few hundred trees usually in the back yards of houses for the most part neglected save for picking berries once a year.

the sources of infection of any practical importance. By the end of the first year (1913-14) the scale had been detected in no less than sixty-eight estates. The pest spread over the State with the same rapidity as it had displayed in Ceylon where it took only four years to cover the entire island. This phenomenal rapidity of spread has been observed in other parts of the world where the pest occurs. In less than three years from the first serious outbreak, the insect was to be found spread over the entire coffee-growing area of the State, save a small portion of Koppa Taluk in the North-Western corner.[1]

THE LIFE HISTORY OF GREEN BUG.

The study of the pest was undertaken soon after the outbreak was reported. No complete life history had been published. Green published in 1886 a brief account of the pest. Koningsberger and Zimmermann[2] published two much fuller accounts in 1897 and 1901. Lefroy[3] wrote a brief account in his Insect Pests of Coffee published in 1903. Within the past few years the pest has engaged the attention of a number of workers in Java, among whom may be mentioned Keuchenius.[4] These various publications represent, for the most part, the results of observations made under conditions of climate and cultivation which differ considerably from those obtaining in South India. It became necessary therefore to make a thorough study of the pest under the conditions existing in Mysore.

Detailed Description of the Pest.—The general appearance of the pest as seen with the naked eye has already been described. Under a lens, the eyes are seen as conspicuous black spots near the margin. The anus is marked by two brown triangular plates with the longer

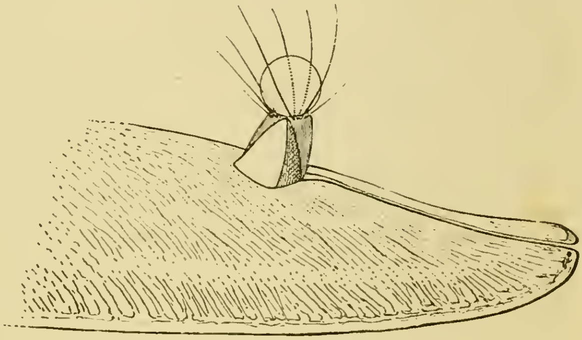
[1] During the present year (1917) the pest has put in its appearance in this locality also, so that no section of the coffee area in Mysore can now be considered free from the pest.

[2] Koningsberger, De Dierlijke Vijanden der Koffiecultuur op Java, Part I, 1897 pp. 8-15; Koningsberger and Zimmermann, Do. Part II, 1901, pp. 7-30, Mededeelingen uit 'Slands Plantentuin,' 20 and 44.

[3] Lefroy, Insect Pests of Coffee, Bulletin No. 2, Imperial Department of Agriculture, 1903.

[4] Keuchenius, Enkele Beschouwingen over de Schildluizen van de Koffie, Med. van het. Besœkisch Prœfstation No. 16.

sides in apposition. From the hind end of these plates and in the median line a slit proceeds to the posterior margin dividing the hind end into two lobes called the anal lobes (see Text-fig. 1). When the bug is gently pressed the anal plates separate and through the opening appear eight wax-covered spines surrounded by a fluted collar, the everted end of the alimentary canal. These spines open out like a flower and a drop of liquid appears which bursts and falls quite clear of the bug (see Text-fig. 2). The fluid is the saccharine substance which is found covering the upper surface of the leaves of infested plants, the so-called honey dew. If the bug is turned on its back, three pairs of legs and the mouth can be observed. On the under surface of the abdominal portion of the body faint traces of segmentation are visible under the microscope. The margin is found to have, at short intervals, a series of spines with frayed ends. At two points on each side there are stouter spines, the central one in each group being twice the size of the other two. These mark the end of the grooves proceeding from the spiracles or breathing pores which are situated at some distance from the margin. There are two pairs of spiracles, the first pair a little behind and away from the origin of the first pair of legs and the second pair between the second and the third pair of legs. The spiracles look like shortened stethoscopes. The grooves from these to the margin are called the stigmatic clefts, and are usually filled with a white waxy secretion which gives them the appearance, under a lens, of faint white lines. The upper surface of the insect shows small translucent spaces which are oval or round. The antennæ or feelers are seven-jointed, the third and fourth longest and sub-equal, the seventh nearly equal in length to the fifth and



TEXT-FIGURE 2.
Posterior end of green bug (*Coccus colemani*) showing everted anus and drop of honey dew excreted.

sixth together. Text-fig. 1 shows the relations of the various structures described.

Green's description of the pest is as follows:—

Lecanium viride, Green.[1]

Lecanium viride, Green; Observations on the Green Scale Bug in Connection with the Cultivation of Coffee; Entomologists' Monthly Magazine, p. 248, 1886.

Adult ♀, bright pale green, with an irregular but very distinct loop of blackish spots on the middle of the dorsum. During treatment with potash, the colour changes to dull orange. Dried examples become dull fulvous, and also the chain of dark spots. Eyes conspicuous, black, close to margin. Anal scales minute, yellowish. Form oval; rounded behind, subacuminate in front; sometimes symmetrical, the development on one side suppressed by contact with a prominent vein of the leaf. Moderately convex above, more particularly in females containing ripe ova. Margin very thin. Skin soft, never strongly chitinized. In old individuals the dorsum is almost smooth; but before the body becomes tense with eggs, a slight median logitudinal, and two transverse ridges are noticeable, the latter above stigmatic areas. Above the abdomen are three series of shallow depressions on each side of median ridge, defined by indistinct transverse and longitudinal ridges. Stigmatic clefts small and inconspicuous. Stigmatic spines 3, stout, pointed, the median one twice as long as the others and curved at the extremity. Anal cleft from one-sixth to one-fifth total length. Margin with short curved hairs, the extremities divided into several points, set at rather long intervals; submarginal tubercles, three or four on each side. Antenna seven-jointed; third and fourth longest, subequal; seventh nearly equal to previous two together. Antennal formula, (3,4), (1,2,7), (5,6) or (4,3), (1,2,7), (5,6), or (3,4), (1,2,7), (5,6); sometimes an incomplete division on the fourth joint. Legs well-developed, moderately stout, claw stout, curved; ungual digitules broad and spatulate, extending well beyond anal claw; tarsal digitules long and slender, dilated at extremity, extending beyond ungulæ. Scales of anal operculum, triangular; base shortest, concave; inner ridge longest, approximately straight; outer edge slightly shorter than inner, convex. Anal ring with eight hairs, two of them much more slender than the remainder. A scattered arch of circular wax glands (with multilocular orifices as in Diaspidinæ) enclosing the genital orifice. Derm with large scattered, rather indefinite, round or broadly oval translucent spots. These spots are rather difficult to demonstrate and can only be made out in a good preparation. Length 2·50 to 3·25 mm. Breadth 1·30 to 2 mm. Male unknown in any stage. The species appears to be reproduced, in this country, by an asexual process, (partheno-genesis) alone; though it is quite possible that, in its native country, sexual reproduction may be normal.

The insect is ovoviviparous, the eggs being hatched at the time of, or immediately after extrusion. Under an adult female a mass of empty egg-skins will be found, with usually some half-dozen or more

[1] Green, Coccidæ of Ceylon, p. 199.

active larvæ. Occasionally one or two pale green eggs are found but this is the exception. A constant succession of larvæ is produced during the life of the insect.

The newly hatched larva is pale green, of normal form, rather broadly oval and very flat ; posterior extremity broadly cleft, the sides of the cleft occupied by the triangular anal scales between which projects a pencil of white waxy matter supported by the hairs of the anal ring. The caudal setæ spring from the tips of the anal scales, and are nearly half the length of the body of the insect. Antennæ six-jointed. Feet with four knobbed hairs (digitules); the tarsals longest and one of these much stouter than the other. Marginal hairs of body simple. Eyes conspicuous, black. Length 0·35 mm.

Female of second stage similar to adult, but smaller and flatter, and without the conspicuous black loop noticeable on the back of the adult.

Habitat :—Originally noticed on coffee (both Liberian and Arabian), but now almost omnivorous. Some of the better known plants upon which it occurs are :—Cinchona succirubra and officinalis, Citrus (various species), Tea (occasionally), Psidium guyava (guava), Manihot ceara, Manihot para (Para rubber), Manihot utilisissima, (tapioca) Gardenia, Ixora, Plumiera, and numerous garden shrubs. Amongst indigenous plants, Antidesma bunius, Hiptage madablota, Callicarpa lannata, Moesa indica, and several species of Loranthus may be mentioned.

The insects, in all stages, are crowded on usually the under surface of the leaves and on the young shoots of the plants more frequently along the midribs and veins.

The Formation of a New Species.

Green's description no longer applies to the green bug as it occurs in Mysore. Apparently a remarkable change has taken place in this insect since its appearance here. The earlier specimens sent in for identification answered in detail to the description of Green. But when specimens received about a year later were examined, the antennal joints were found to be no longer seven in number. They had become reduced to three, all but the first two having coalesced. Several hundreds of specimens were then examined from all parts of the State and from the Nilgiris and the Shevaroys and all showed the reduction, though, in some, faint traces of additional segmentation were found. The form with seven-segmented antennæ has been found only on one plant in Bangalore and nowhere else except, as already stated, among the specimens received in 1913.

There can be no question that the earlier specimens identified as green bug answered to Green's description

in all details. There is in the laboratory of the Department a microphotograph of one of these which shows seven segments in the antennæ quite clearly. This microphotograph is reproduced on Plate III, Fig. 1. Moreover, a reduction in the number of segments, had it occurred then, would not have passed unnoticed as the seven-segmented antennæ is one of the specific characters of the species as described by Green.

This sudden reduction in the antennal segments from seven to three made it appear highly probable that the insect was very variable. Mr. Newstead had, as early as 1898, described a variety of *C. viridis* under the name *Coccus viridis, var. africanum* and this variety was, about fifteen years later, given specific rank by him. It was thought advisable, therefore, to make a study of the insect from various parts of the world. Specimens have been obtained from Ceylon, Java, Seychelles and Hawaii. Those from Ceylon, Seychelles and Hawaii are still true to Green's original description. With regard to those from Java, Mr. Keuchenius writes as follows in a letter received from him :—" The variability of *Lecanium viride* is a difficult and troublesome question. Green, in his standard work, does not mention at all any variability and therefore, in the beginning, I had thought that I had to do with two different species; but afterwards I came to the conclusion that *L. viride* varies strongly. In the same locality and in the same garden and on the same kind of coffee (but on different trees) one may find the following forms :—(1) A large form with a very flat body which is of a green colour, (2) a smaller form with a more elevated body and of a darker dirty greenish colour. Between these extremes there exist all kinds of nuances." The Mysore form is different from all the other forms examined and has been described as a new species by the junior author in a paper read before the meeting of the Indian Science Congress held in 1917. The following is his description of the new species:—

COCCUS COLEMANI, NOV. SP. Adult female.

Characters as in C. viridis but antennæ three-segmented, the first and second segments being subequal the third from five to six times the length of the first segment and having a number of apical and subapical hairs. The dorsal "x"-shaped carina not found in any stage. Dermal cells more round than oval, few and scattered over the dorsum

and from 30 to 80 microns apart. Colour pale lemon-yellow to greenish-yellow. Shape oval, the anterior end being narrower but liable to variation in specimens fixed on to the sides of the veins of leaves in which the anterior end may be more or less acuminate and either right or left side may be shortened. The insect is ovoviviparous but a few eggs are found laid occasionally.

Reproduction continues for about a month and a half after reaching the adult stage. The number of young may reach over 500.

The newly hatched larva is very pale lemon-yellow, broadly oval. The antennæ three-segmented as in the adult. The number and relative lengths of the segments as in the adult. Other characters as in the nymphs of C. viridis. Adult female from 2 mm. to 4 mm. Male unknown.

The Life History of Coccus colemani.

The life history hereafter described is of this new species. It is important to emphasize this point because apart from the structural differences between *C. viridis* and *C. colemani* there is a considerable difference in the reproductive powers. Green gives the number of young produced as seldom more than 20, but later on corrects himself by saying that immature eggs have been found inside the body after the first brood (of apparently 20) had hatched. What the total number of young produced by an individual is has not been stated.

Koningsberger and Zimmermann[1] in their description of the Javan form point out that the number of eggs in an individual indicated very much greater powers of reproduction than Green described. They found as high as 150 eggs in an individual. Their observations have been recently confirmed by Keuchenius[2]. There can be no doubt from the size of the Javan forms that their reproductive powers must be much more than those of the much smaller Ceylon forms. Green[3] was not wrong so far as the Ceylon form is concerned. A number of specimens received from Ceylon, when microscopically examined, did not show more than 100 eggs in the body. There can be no doubt that, in the case of the several forms called green bug, in addition to the usual factors of size, kind of host plant, etc., another important factor has

[1] An Instance of Mutation; Coccus viridis (Green) a Mutant from Pulvinaria psidii (Maskell), read before the Indian Science Congress 1917, by Mr. K. Kunhi Kannan.

[2] Loc. cit., part 2, p. 10.

[3] Loc. cit., part 12.

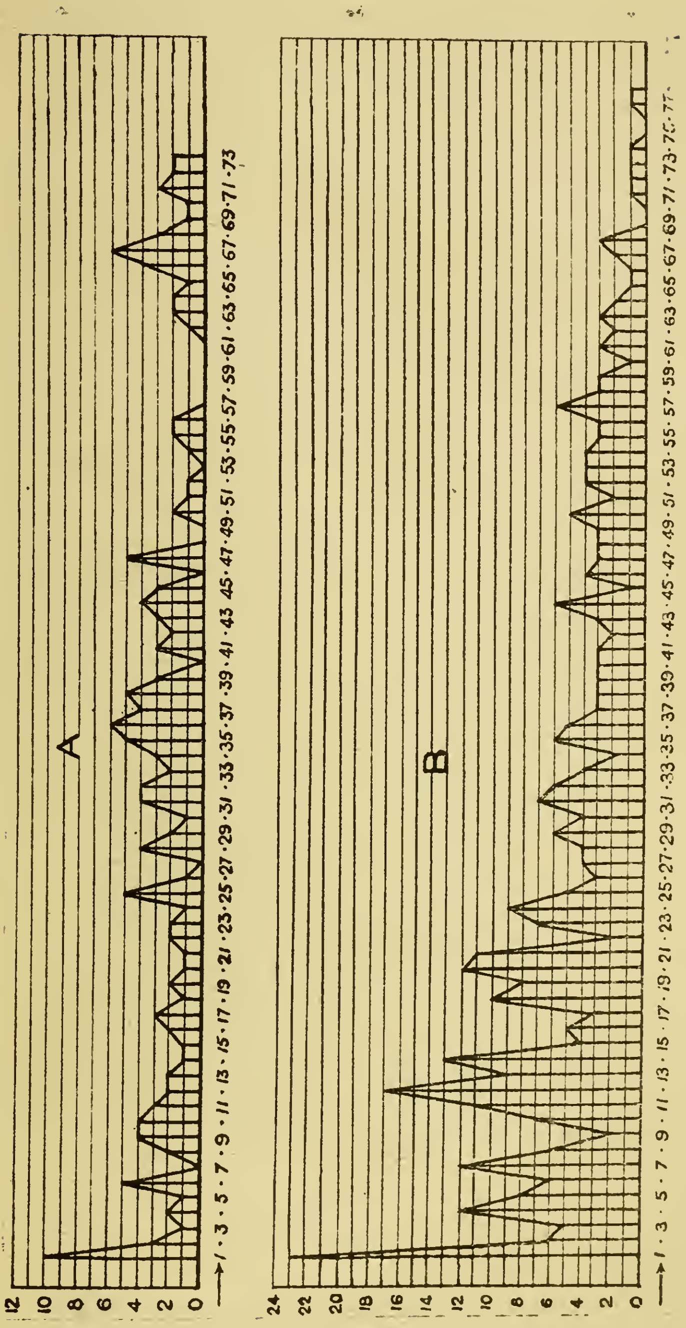
been introduced by their enormous variability. In Mysore the number of young brought forth has varied from 50 to 580. The following charts (see Text-figs. 3 and 4) show for each individual reared in the insectary the number of young produced from day to day and the total for the whole period of life.

This great variation in the number of young produced depends on various different factors of which the size of the bug, the age of the leaf on which the bugs fix and the place of fixation are only a few. The bugs on the more tender and young leaves and on the developing shoots are healthier and grow more rapidly. Those bugs along the veins and on the under side of the leaf are in more favourable situations than those on the upper surface of the leaves. There are, in all probability, other factors, such as humidity, temperature and the vigour of the plant, whose influence it has not been possible to determine.

The bugs which have begun to reproduce can be recognised by the more whitish appearance at the posterior end, due to the white egg shells which accumulate beneath. The posterior margin is also slightly tilted up to allow the young to crawl out. On some plants, especially those blackened by sooty mould, this is quite conspicuous. The upper surface of the body may be thrown into minute folds, due no doubt to the posterior end of the body being forced up by the accumulation of the young underneath.

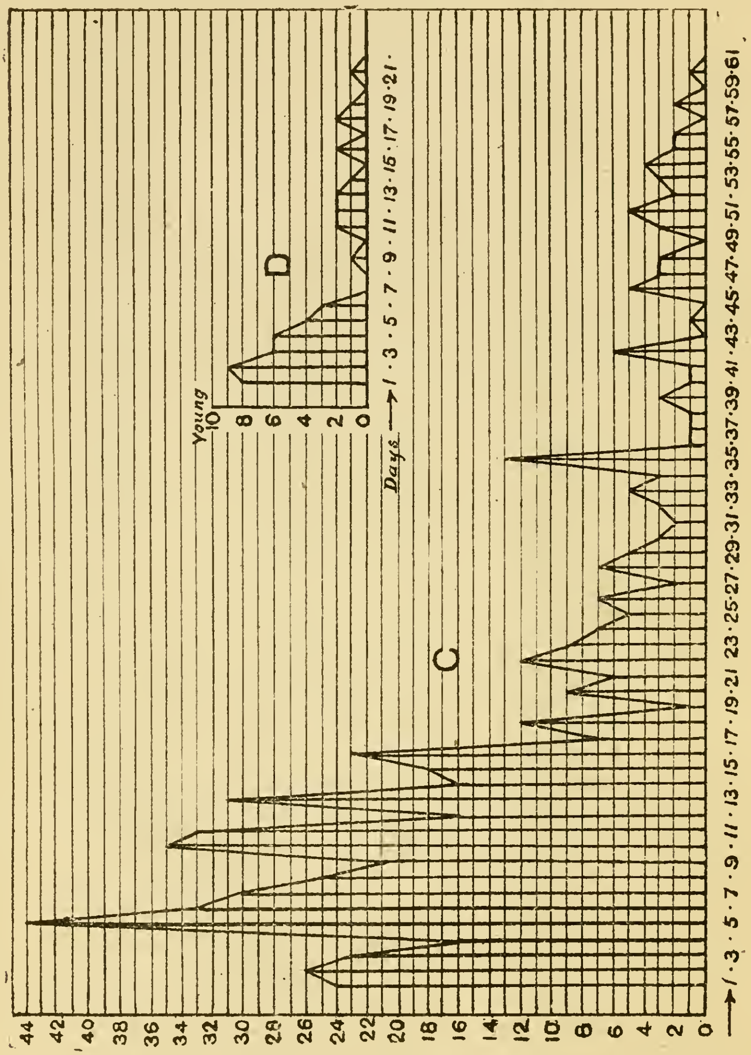
The insect is ovoviviparous; in other words, the eggs develop inside the body and hatch at the time of or immediately after extrusion. The under surface of the abdomen is slightly arched to allow space for the young which remain beneath the mother for some time. When the scale is lifted off from the leaf one or two eggs may occasionally be detected amidst the young entangled in the egg shells.

The process of fixation of the nymphs appears to be a difficult one and takes some considerable time. At the commencement of the operation the young nymph is found at an angle to the surface of the leaf, the hind end touching the leaf. The tip of the proboscis alone is apparently inserted during this period which is very short. It is followed by a slant in a reverse direction the anterior end being nearer the leaf. When balanced this way the bug



TEXT-FIGURE 3.—Chart showing the production of young by two coffee green bugs. The vertical divisions represent the number of young produced; the horizontal division, period in days through which the production of young took place.

moves sideways apparently working the proboscis somewhat like a drill. When part of it has thus penetrated the tissues, the bug completes the process by gently curv-



TEXT-FIGURE 4.

Charts showing the production of young by two coffee green bugs. Explanation of charts as for Text-Figure 3.

ing the abdomen downwards and upwards, probably so as to make the thoracic portion tense. This has apparently the effect of bringing the buccal apparatus more at right

angles to the surface of the body. The force exerted by these means is considerable, as the proboscises of bugs have been found driven through the bodies of other bugs situated beneath them. Rarely the bug may be found completely lifted off the leaf and balanced on the straightened proboscis. Once the fixation is effected, the contact with the leaf becomes so close that the outline of the bug may be clearly impressed on the surface of the leaf.

As with all insects, the development of the green bug is accompanied by a periodic casting off of the skin which is known as moulting. The number of moults which normally occur has not been definitely established. Green[1] states, "The number of stages separated by the casting of the skin is believed to be three in the female, but as the process of moulting in this family is very obscure, the point requires confirmation." Koningsberger and Zimmermann[2] state that after two moults the adult stage is reached. Careful observations in the insectary here have shown that the number of moults in *C. colemani* is three and not two. There are thus three nymphal stages or instars preceding the adult stage.

The process of moulting in the green bug as found in Mysore possesses certain peculiarities which have not been clearly elucidated. The first moult appears to be normal; the whole outer covering being involved, including that of the rostral apparatus and the anal plates. The second and third moults show a difference in that the skin on the ventral surface only seems to be cast off by what appears to be a peristaltic movement of the under surface of the body.

The cast-off skin comes out between the anal lobes as a twisted shred, the first part to appear being that from the anterior end. The chitinous plates and the upper skin of the anal lobes are also involved but not any dorsal portion further forward. An ink spot made on the dorsum of the anterior part remains after the moult is completed, showing that the dorsal skin in this region is not cast off. The moulting described is in accord with the observation made with regard to some other scale insects such as *Aspidiotus*. Green[3] writes, "The process of moulting in the sub-family (to which green bug belongs) has remained

[1] Green, Loc. cit., p. 173.
[2] Koningsberger and Zimmermann, Loc. cit., p. 7.
[3] Green, Coccidæ of Ceylon, p. 173.

obscure. I have myself observed the shedding of the skin in the genus *Lecanium*. The exuvium is very thin and delicate becoming twisted up into a minute formless shred as it is pushed off the body. The old skin may sometimes be seen still adhering to the posterior extremity of a recently transformed female *Lecanium*. It is difficult to understand how such genera as *Ceroplastes* or *Vinsonia* in which the waxy test is closely adherent to the body of the insect through life can get rid of their exuvia. It is possible that the cast skins may become incorporated into the waxy test. The fact that in *Ceroplastes* the pad of opaque wax that covers the dorsum of the larva may always be recognised as a central spot on the test of the adult and the pointed lateral processes of the larval test can be distinguished at intervals in the sub-marginal area of the fully formed test, lends colour to this theory of incorporation."

The process of moulting in green bug described above is the same as that found in the mealy bug and brown bug, and there can be no longer any doubt as to the theory of incorporation advanced by Green. How the marginal separation of the top and ventral skins is effected is not clear. Green bugs are occasionally found with the whole body tense, translucent and markedly convex. This may possibly help in the separation. It has to be noted, however, that this feature does not appear during or immediately before a moult. The bugs when casting skins cannot be distinguished from others save for the shred of skin gradually rising between the anal lobes. The moulting is followed by a period of restlessness, the bugs seeking new places of attachment. With the third moult the bug reaches the adult stage. After the last moult, the bug becomes gradually convex on account of the development of the eggs within.

Description of Stages or Instars.

1st Instar.

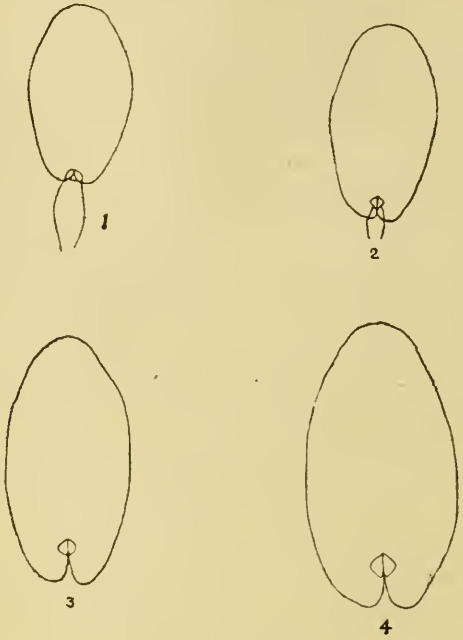
Light lemon-yellow. Broadly oval. The hind margin interrupted in the middle, the ends curved inwards and disappearing beneath the apices of the anal plates which are completely within the oval outline. The anal plates are terminated behind by two long filaments. The eyes are near the margin. The abdominal segments are indicated by minute folds. The thoracic divisions are also traceable but with diffi-

culty. Antennal segments three, the first two subequal, the third about six times the length of the first. The anal plates do not meet throughout their length, their apices remaining apart (see Text-fig. 5, 1 and Plate III Fig. 3.)

Length 0·3 mm.

2nd Instar.

Almost transparent showing distinctly the air tubes and their larger ramifications. During this instar the anal lobes grow backwards so as to become closely approximated behind the anal plates (see Text-fig. 5, 2). The hind end is consequently narrower relatively to



TEXT-FIGURE 5.

Outline of *Coccus colemani* during the different instars. 1. First instar. 2. Second instar. 3. Third instar. 4. Adult.

the front end than in the first instar. The anal filaments present.

Length 0·5 mm.

3rd Instar.

Semi-transparent with the loop seen very faintly. The anal lobes have grown still farther backwards (see Text-fig. 5, 3). The filaments of the anal plates have disappeared and in their places appear three stout setæ. Abdominal segments still visible from above but only towards the margin. Antennæ as in previous instars.

Length 1 mm.

Adult.

The bug is more opaque and yellowish. Owing to the farther

growth of the anal lobes the anal plates now lie removed from the posterior end of the body by a distance equal approximately to one-sixth of the total length of the insect (see Text-fig. 5, 4).

Abdominal segments only visible from below. The body at first flat becomes more or less convex and the loop turns from brown to black. Antennæ as in first instar.

Length 1·3 to 1·5 mm.

N.B.—The measurements given above are of nymphs and adults immediately after moulting and are to be taken as average figures.

The length of life varies from 89 to 214 days and the number of young from 50 to 580. The first moult takes place within two days after hatching. The second moult takes place about a fortnight after the first and the third from eleven to eighteen days after the second. The tables on pages 23 to 25 (Tables I and II) summarise the results of rearings in the insectary in Bangalore.

Once the bug fixes itself, it moves of its own accord usually only after moulting. Movements may, however, be induced by the growing difficulty of finding nutriment. When leaves or twigs are overcrowded, the bugs may become disturbed from their places of fixation. The marked preference for very tender leaves has already been mentioned. Bugs may be detected on the leaves of the opening buds when elsewhere they cannot be found. On these they grow much faster. The upper surface of the leaf is seldom selected for fixation and the few that are fixed there are much smaller than those on the under side of the leaf. The green-coloured portions of the twigs are also suitable places for fixation, but it is rarely that bugs are found on the brown-coloured portions, and when found there they are invariably more yellow in colour and the black loop is either inconspicuous or not seen at all. As has already been noticed by Green, Koningsberger and Zimmermann and Keuchenius, the bug, when fixed, has almost invariably its anterior end towards the base of the organ to which it is attached.

The normal shape of the bug is oval with the anterior end narrower. But this shape is retained only when the bug is fixed on the free surfaces of twigs and leaves. Along the veins, the bugs are asymmetrical, the right side or the left side according to the side of the vein selected being hindered in development by the convexity of the vein. There is also a twist in such specimens.

The convex surface of the vein is usually not sought. Bugs in such situations are usually narrower and more

TABLE I.—RECORD OF MOULTS OF C. COLEMANI.

Date of hatching of the nymph	Date of			Number of days taken			Remarks
	1st moult	2nd moult	3rd moult	Hatching to 1st moult	From 1st to 2nd moult	2nd to 3rd moult	
22-12-14	24-12-14	13-1-15	...	2	20	...	5-2-15. Nymph was not found on the plant.
23-12-14	25-12-14	13-1-15	...	2	19	..	18-2-15. do do
18-2-15	20-2-15	4-3-15	...	2	12	...	15-3-15. do do
18-2-15	20-2-15	4-3-15	...	2	12	...	20-3 15. Nymph was found dead in the vaseline.
15-3-15	17-3-15	30-3-15	...	2	13	...	8-4-15. Nymph was found dead.
15-3-15	17-3-15	1-4-15	...	2	15	...	5-4-15. Nymphs were found dead.
15-3-15	17-3-15	1-4-15	...	9	15	...	
15-3-15	17-3-15	2-4-15	25-4-15	2	16	23	6-6-15. Reproduction begun.
9-4-15	10-4-15	25-4-15	24-6-15	1	15	...	12-5-15. The stem of the plant was cut off probably by rats.
30-5-15	31-4-15	13-6-15	24-6-15	1	13	11	21-7-15. do do
30-5-15	1-6-15	13-6-15	24-6-15	2	12	11	1-8-15. do do
30-5-15	1-6-15	15-6-15	29-6-15	2	14	14	2-7-15. Nymph of 3rd moult preserved in glycerine.
15-6-15	17-6-15	1-7-15	...	2	14	...	2-7-15. do do
15-6-15	17-6-15	1-7-15	14-7-15	2	14	13	
15-6-15	17-6-15	Cast skin not found	15-7-15	2	14	...	
15-6-15	17-6-15		16-7-15	2	14	...	11-8-15. Reproduction begun by one of the bugs.
15-6-15	17-6-15	Do	26-7-15	2	14	...	

TABLE II.—CHIEF FEATURES IN THE LIFE HISTORY OF COCCUS COLEMANI.

Reference	Date: Introduced on to coffee plant	Date: When traces of black loop observed	Date: When reproduction began	When and total number of days on which reproduction ceased temporarily	Date: When reproduction ceased finally	Date: When bug began to turn brown	Total number of nymphs hatched	Number of days: From the date of hatching to that of appearance of black loop	Number of days: From the date of appearance of black loop to that of reproduction	Number of days: From the date of hatching to that of reproduction	Number of days: For the period of reproduction	Number of days: For the appearance of brown colour after reproduction	Number of days: Length of life
1/d	13-5-15	21-7-15	3-8-16	1915 August, 15, 20, 22, 24 to 31st (19 days.)	9-9-15	13-9-15	70	69	13	82	37	4	123
1/c	9-8-15	19-9-15	6-10-15	1915 October 14 and November 21, 25, 26. 28, and 30th. December 2 to 7th, 12th, 17 to 20th, 30 and 31st. 1916 January 8th, 10 to 17th, 19 to 22nd. (36 days.)	25-1-16	19-2-16	124	41	17	58	111	25	194
2/a	15-10-14	28-11-14	13-12-14	1914 December 19th, 1915 January 8, 21, 27, 29 and 30th, February 3, 7, to 11th. (12 days.)	24-2-15	10-4-15	162	44	15	59	73	11	146
2/c	16-2-16	19-3-15	26-3-15	1915 April 18 to 22nd. November 24 to 28th. May 1, 3, 5 and 9th. (14 days.)	14-5-15	16-5-15	294	31	7	38	49	2	89

2/d	26-3-15	20-6-15	7-7-15	1915 July, 9, 13, 14, 15 19, 20, 22, 24, 25, 27, 28, 30, 31st. August 1, 2, 7, 10, 11, 20, 22, 23, 25, 26, 27, 30, 31st. September 5, 10, 14, 20 to 23rd, 27th Sept. to 6th October 1915, October 8th, 14 to 18th, 21st. (50 days.)	25-10-15	26-11-15	88	86	17	103	110	1	21
3/b	14-12-14	30-1-15	7-2-15	1915 February 13, 14, 16, 21, 23 & 26th. (6 days.)	28-2-15	22-3-15	50	47	8	55	21	22	98
3/d	27-4-15	21-6-15	8-7-15	1915 July, 16, 27, 28 and 29th. August 22nd. September 1, 3, 9, 10 and 29th. October 5, 16 and 19th. (13 days.)	24-10-15	28-10-15	198	55	17	72	108	4	184
3/e	11-7-15	13-8-15	23-8-15	1915 October 5, 19, 21, 24, 25, 26, 28, 29 and 31st. (9 days.)	2-11-15	4-11-15	228	33	10	43	71	2	116
3/f	23-8-15	27-9-15	8-10-15	7th November 1915. (1 day) ...	10-11-15	22-11-15	192	35	11	46	33	12	91
5/a	18-10-14	25-11-14	8-12-14	1915 January 19, 21, 25th. Feb. 2 and 4th. (5 days.)	6-2-15	24-3-15	580	38	13	51	60	46	157

convex. Several other curious forms are produced by individual methods of fixation. In some, the anterior end appears as a distinct lobe projecting from the body; in others, curious projections may appear on the anal lobes.

Feeding.

Convulsive movements may be seen through the chitin, while the bug is feeding. These are probably due to the pumping action of the alimentary canal. Feeding apparently continues until the death of the insect, but no definite statements can be made in this regard. Mealy bugs, previous to oviposition, seek such situations as folds of dry leaves, the dry scales of the bark, etc., where nutriment is out of the question. Specimens of green bugs were found alive even after a burial under ground of about twenty days. Nevertheless it appears probable that feeding continues at least throughout the period of reproduction. The interval between the end of reproduction and the death of the insect varies from one day to as many as four days, the commencement of discolouration of the bug being taken as evidence of death.

The course taken by the proboscis in the tissues of the leaf and the tissues from which nourishment is chiefly drawn have formed the subject of study by Keuchenius in Java, and as the positions occupied by our form on the leaves and twigs is much the same, it is probable that this represents the method of feeding here also. The following account is abridged from his description:—[1]

Lecanium viride (*Coccus viridis*) usually, in penetrating the leaf, pierces the cuticle of the epidermis in the middle of an epidermal cell. One of the results of penetration is commonly a certain amount of plasmolysis in the cells penetrated as well as in the neighbouring cells but the original turgor is later on restored even in the cells which have been pierced. The cells penetrated show no signs of death and the cell walls do not turn brown. The saliva which is emitted from the proboscis during the penetration first appears as irregular masses and only gradually takes on the form of a regular approximately uniform layer which later on hardens into a

[1] Keuchenius, Loc. cit., p. 22.

sheath—the so-called salivary sheath. The course which the proboscis takes in penetrating the leaf tissue can be readily traced by these salivary sheaths which, of course, remain after the withdrawal of the proboscis and appear as highly refractile colourless threads. The proboscis follows the most irregular course in penetration, the salivary sheaths branching in all directions. However, the end of the proboscis can always be found on the outer margin of the phloem and at the ends of the medullary rays, and it is these two parts of the tissue which appear to be particularly attacked by the insect. The result is that these tissues as well as the surrounding cells even of the cambium and wood become completely brown and dead. When this has taken place the insect withdraws its snout somewhat and seeks out a fresh point of attack on a new medullary ray.

Keuchenius considers that the death of the attacked cells is a direct result of the sucking action of the bug and is not due to any poisonous secretion which it might inject into the leaf tissue during the process of feeding.

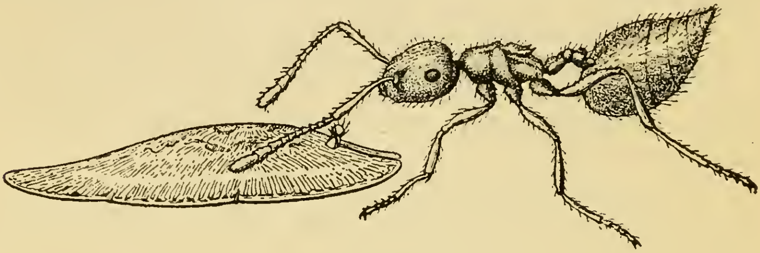
Excretion.

The sole excretion seems to be the honey dew The manner of its ejection has already been described. Ants attend the bug for the sake of this sugary excretion. They tap the bug gently with their antennæ in the neighbourhood of the anal plates, until it yields a drop of the fluid in response to these solicitations. The ant feeds on the drop before it has a chance to burst and then proceeds to "milk" another bug in the same way.

In spite of the large quantity of honey dew thus used up by ants, there is enough left over to cover the upper surface of the leaves with a fine layer of shining transparent syrup. This is an excellent medium for the growth of the fungi called sooty moulds, which grow in it and thus blacken the leaf. The fungi do not directly harm the leaf as they derive their nourishment solely from the honey dew. But an opaque film covering the leaf and interrupting the sun's rays may injuriously affect the plant. Not uncommonly in such cases the leaves are seen to drop off before their time.

The Relationship of Ants to the Green Bug.

The general facts of the relationship between ants and sucking insects such as scale insects, plant lice, leaf hoppers, etc., are well known. All of these groups of insects produce a sugary excretion known usually as honey dew which the ants take up with avidity. Text-fig. 6 shows a cock-tailed ant (*Cremastogaster sp.*) "milking" a green bug. The benefit derived by the ants from this relationship is obvious. It is, however, not always so apparent just what benefit, if any, is derived by the insects which are visited.



Text-Figure 6.

An ant (*Cremastogaster sp.*) in the act of "milking" a green bug.

In some cases, as, for instance, that of the corn root aphis (*Aphis maidi-radicis*) in America, the insect is practically helpless without the assistance of a species of ant (*Lasius niger-americanus*). When the plants upon which these aphids live are no longer available, the ants carry them into their nests and keep them until the plants appear again. In South India an example of quite close relationship between scale insect and ant is that of the so-called cock-tailed black ant *Cremastogaster sp.* and the scale *Lecanium formicarii*. This latter is found only in the nests of the ants and if the ants' nests are broken into the scale insects are carried away just as carefully as are the pupæ, larvæ and eggs of the ants themselves. It is obvious that, in such cases, any measures towards the checking or destruction of the scale insects or plant lice would be incomplete if they did not take into consideration this relationship.

In other cases, the relationship is not nearly so close and in these it is always a question whether the ants are in any way particularly beneficial to the scale insects. Such a case is presented by the green bug. The most casual observation shows that this scale insect is visited

by a number of different species of ants, but there is, as far as we are aware, no record of the scales being in any way protected by any of these ants. Several planters have, it is true, reported that they have seen the green bug carried by the large red tree ant (*Oecophylla smaragdina*) but where they carried them and what they did with them no one had observed.

This question of the relationship between ants and green bug has received a great deal of attention from workers in Java. Koningsberger and Zimmermann[1] were unable to observe the transference of green bugs through the agency of ants and at the same time established the fact that the green bug is able to live and multiply for a long period without being visited by ants at all. Keuchenius[2] has studied particularly the relationship between the two ants, *Oecophylla smaragdina* and *Plageolepis longipes*, and green bug. He comes to the conclusion that, of these, the latter was useful rather than harmful as it neither transfers the green bug from place to place, aids its development in any way nor destroys its natural enemies. On the other hand, he considers that this ant plays a role in the spread of the fungi to be described later which form one of the most important checks to the pest; according to this author the ant also reduces the amount of sooty moulds by decreasing the quantity of honey dew upon which these fungi grow. On the other hand, he concludes that the large red tree ant (*Oecophylla smaragdina*) is harmful in coffee estates in that it aids in the development of green bug and protects it from its enemies.

The most careful series of observations and experiments which have been carried out on the subject of green bug and its associated ants are those of van der Goot.[3] The second of his papers is largely devoted to experiments on the relationship between two ants (*Plageolepis longipes* and *Dolichoderus bituberculatus*) on the one side and green bug on the other. His conclusions

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[1] Koningsberger and Zimmermann, loc. cit, Part II, p. 14.

[2] Keuchenius, Onderzoekingen en beschouwingen over eenige schadelijke Schilduizen van der Koffie Kultuur op Java, 1915, p. 37.

[3] van der Goot, Over de Biologie der Gramang-mier (Plagiolepis longipes, Jerd.). Med. van het Proefstation Midden-Java, No. 1, 1915, and Verdere Onderzoekingen omtrent de oeconomiche Beteekenis der Gramang-mier, Med. van het Proefstation Midden-Java, No. 22, 1916.

are that both these ants have a marked influence in increasing the numbers of green bugs on a coffee tree. The presence of these ants, according to the results of his experiments, are beneficial to the green bug in four ways:—

1. The death rate of green bugs is much smaller where ants are present than where they are absent;
2. The development of the green bug is more rapid where they are present;
3. They serve to prevent the parasitising of green bug to a considerable degree; and
4. Their presence leads to a great increase in the progeny of the green bug.

Of the two ants, *Plageolepis longipes* had a very much more beneficial effect upon the development and multiplication of green bug than did *Dolichoderus bituberculatus.*

While the experiments of van der Goot deal with the direct effect of the ants on the development of green bug on a tree, he does not appear to have carried out any experiments to decide whether any ants play a role in the spread of the pest. As has already been stated, reports of observations of the actual carrying of the green bug by ants have been received. In addition, the junior author observed the cock-tail ant (*Cremastogaster sp.*) carrying green bugs and when these were followed, it was noticed that they dropped them into the dry hollow of a coffee tree where there was no chance of the bugs obtaining any food. Where green bugs are found in ants' nests formed out of the leaves of coffee tree or other host plants, they too may feed and multiply within the nests themselves. But where nests are made in the ground it is difficult to understand what the object of the transfer is. Do the bugs in these cases quit the nests soon after they are brought in or do they remain dormant to tide over the unfavourable conditions which may prevail in more exposed situations? To decide these points, if possible, the following experiments were carried out.

Two coffee plants in pots were placed in shallow trays containing kerosened water. One of these was infested with green bug and the other not. A nest of the red tree ant (*Oecophylla smaragdina*) was introduced into the uninfested pot on the 13th March 1915. On

the following day, a new nest was found on this tree made by the ants out of coffee leaves. As soon as it was completed, the pots were connected by a tape (see Plate III, Fig. 2). The ants soon crawled over to the infested pot and in about two hours the first bug was carried into the nest on the uninfested plant and later on several more were taken.

From the very large number of ants found crawling over every part of the infested plant, it was impossible to observe whether the bugs carried over were those fixed on the plant or those moving about. The former appears more probable as, usually, very few bugs move about. The majority of those carried into the nests were immature. It is interesting to note that the particular colony of ants with which the experiment was tried had, in all probability, no previous experience in carrying scale insects. The tree from which it was obtained had no scale insects on it nor were any found in the nest from which the ants were taken. It is, therefore, reasonable to assume that the instinct displayed here is much the same as that displayed by all ants, *viz.*, that of carrying into their nests food material found in the course of their explorations and the scales were probably carried into the nests because it was found they yielded a sugary substance, the honey dew. Why only a few of the many bugs on the plants were carried, and why the instinct did not assert itself more strongly is not clear. Green bugs marked with ink and dropped into the colony were immediately thrown out. Others placed in the way of ants which were on their way to their nest did not attract any attention.

Two more species of ants which have nests under ground (*Solenopsis geminata* and *Tapinoma melanocephalum*) were experimented with. In both the experiments several bugs were carried into the nests.

It was difficult to ascertain, in the case of these two species what happened to the bugs after their transference. Nevertheless the following experiments were tried. The plant in the pot in which the nest was situated and into which the bugs had been carried, was cut near the ground level and the stump was connected by a tape to another uninfested plant. The ants readily went over to this plant but no bugs were carried over. This experiment failing, the pot with the nest was gradually heated from below to force the ants out. The expectation was that

when leaving the nest the ants would take the bugs also along with the eggs and pupæ. But while all the latter were brought to the surface no bugs were brought up although there were nearly twenty in the nest. In another experiment the pot was flooded with water but with the same result.

These experiments give us valuable information as to the relations between the ants and the scale insects. There can be no doubt that those species which feed on the honey dew have a large share in the distribution of the pest. Considering how far the ants travel in search of food and how soon they detect the presence of the scales, their nests must be regarded as distributing centres. This is probably the case even with species which make their nests in the ground although, as already noticed, we have not observed bugs being carried away from such nests. The nests also appear to be convenient shelters from adverse conditions of weather. Nests of *Cremastogaster* in coffee estates were found crowded with green bugs in September when elsewhere they could be detected only after careful search or not at all. In fact, the nests seem to be centres from which infestation starts after the monsoon is over.

To determine the precise difference in the degree of infestation between estates with and without ants' nests, the following experiment was tried. Soon after the monsoon, two blocks equally badly infested and of about four acres each were selected. One had all the ants' nests removed or, as in the case of ground ants, destroyed by carbon bisulphide, and for a considerable area round it. In the other they were left undisturbed. After seven months they were inspected again and it was found that in the block where there were no ants' nests only eight trees showed the bug while in the check there were one hundred and thirty-two infested.

As has already been stated, it has been proved by experiments conducted in Java that ants prevent the parasites of the bugs from approaching them. The bugs attended by ants show less percentage of parasitised bugs than those unattended. It has further been suggested by van der Goot that the tickling of the bugs with the antennæ in some way helps to make them more vigorous.

In South India, Fletcher records having observed the ant, *Camponotus compressus*, Fabr., vigorously defending

a scale insect from the approach of a fly which wanted to parasitise it.

These results are to a great extent confirmed by observations made in Mysore. Two plants of about the same age had bugs introduced on to them. Into one of these an ants' nest was introduced on 3rd February, 1917. On 8th May, 1917, three months after, the plants were examined for parasitised bugs. On the plant with ants no parasitised bug was found, while on the other the percentage of parasitised bugs was 14·3 per cent. A count of the total number of bugs on the two plants gave results the reverse of those recorded by van der Goot. The experiment was started with six nymphs, each of third instar. At the end of three months there were only 67 adult bugs in the pot with ants, against 116 in the one without.

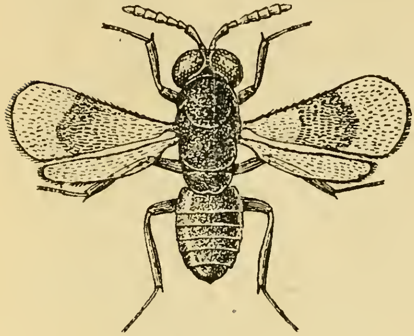
It is too early to arrive at any definite conclusions from the experiments. It may, however, be noted that the only estate in which green bug seems to have obtained a persistent hold in Mysore is one where the species of ant experimented with in Java (*Plageolepis longipes*) is found in abundance. It is also interesting to record that while the percentage of parasitised bugs in the Laboratory compound is as high as 20 per cent, in the estates it is not more than 5 to 7 per cent.

The Enemies of Green Bug.

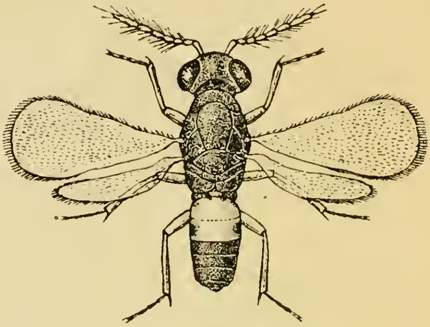
The most important insect enemies of green bug in Mysore are the hymenopterous parasites. These lay their eggs in the body of the insect. The larvæ hatch out and feed inside the body. Apparently the alimentary canal is not affected, for the bug continues to live even when the parasite inside the body is very large. Young may also be produced by the parasitised bugs. There are at least five species of parasites but their efficacy is seriously diminished by a hyper-parasite and, as has already been shown, by the attendance of ants which appear to prevent their approach and oviposition.

Frontispiece, Fig. 4, shows the general appearance of green bugs when parasitised. Such bugs are to be distinguished by their brownish colour which can be readily made out in the figure. Plate I, Fig. 7, shows a green bug with the pupa of a hymenopterous parasite inside of it.

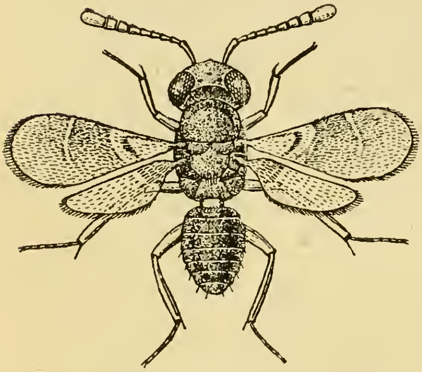
To the left of this pupa and above, is to be seen a yellowish object. This is the grub or larva of a hyper-parasite which is attacking the pupa. Parasites and hyper-parasites in green bugs are shown in the microphotographs reproduced



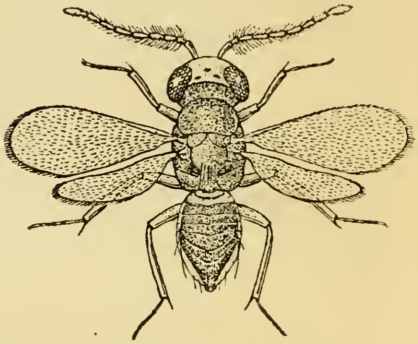
TEXT-FIGURE 7.



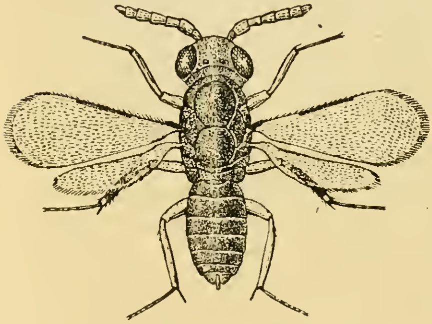
TEXT-FIGURE 8.



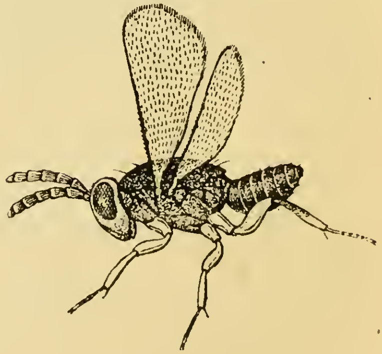
TEXT-FIGURE 9.



TEXT-FIGURE 10.



TEXT-FIGURE 11.



TEXT-FIGURE 12.

TEXT-FIGURES 7 TO 12.—Hymenopterous parasites and hyper-parasites of *Coccus colemani* The identification of these insects and their exact parasitic or hyper-parasitic relationships to the pest have not yet been worked out.

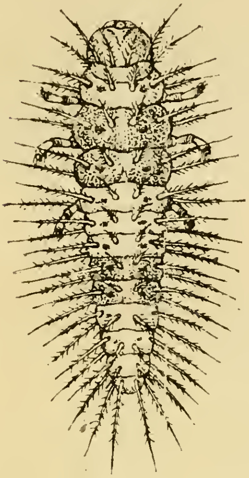
on Plate IV, Figs. 4 and 5. Text-figs. 7-12 show the various parasites and hyper-parasites which have been found up to the present.

Other enemies are the so-called lady-bird beetles. Very few of these have been noticed in the coffee districts of Mysore. The larvæ of *Chilomenes sex-maculata* have been observed feeding on the bugs, but there were very few of these and those few apparently did not relish the pest very much. In Bangalore, attempts were made to accustom lady-bird larvæ found feeding on a mealy bug belonging to an unidentified species, to a green bug diet, but the experiment failed. A third species found attacking a species of scale insect (*Phenacoccus sp.*) also did not relish the new food provided.

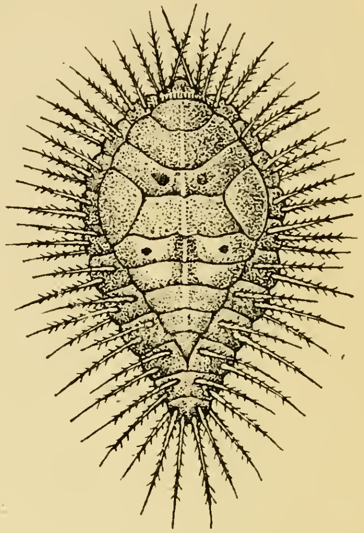
The fourth species tried was *Chilocorus nigritus*, a blue hemispherical beetle which was found to feed both in the adult and larval stages on green bug (see Text-figs. 13-15). The life history of this lady-bird has been studied, and is as follows:—

The beetles lay eggs on the stem especially underneath the scaly bark and sometimes also on the under side of the leaf. The eggs hatch in about a week. The larvæ are small thickset grubs with long serrated spines proceeding from tubercles on the segments (see Text-fig. 11). The second and third segments of the thorax are a little darker and stouter than the rest. The dark colour is also found in the last few abdominal segments but there is a considerable variation in this regard. As the larvæ grow, the darkness of these segments increases, especially of those in the thoracic region. The spines grow longer accompanied by an increase in length of the serrations. The larvæ moult three times before pupation, this latter taking place in the split skin of the last instar (see Text-fig. 13). The life history from egg to adult takes nearly a month, the period being distributed as follows:—Egg, eight days; 1st larval stage (or instar), four days; 2nd larval stage, four days; 3rd larval stage, five days; and 4th, seven days. It has not been possible to study further the details of the life history of the beetle, the presence or absence of parasites, its reactions to seasonal changes and weather conditions. The beetles died too soon. This lady-bird has not been noticed anywhere in the districts of Mysore either on green bug or on other scale insects, but there can be no doubt that, provided it multiplies in sufficient

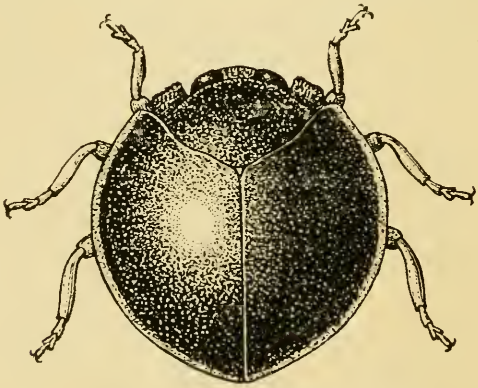
numbers, it will prove a very efficient check. Each larva consumes, on an average, eight bugs a day, and seeing that the life of the larvæ is about twenty days and that the adults also feed on the bugs, the total number accounted for by a colony of these would be considerable. Although the



TEXT-FIGURE 13.



TEXT-FIGURE 14.



TEXT-FIGURE 15.

TEXT-FIGURES 13 TO 15.—Various stages of the lady-bird beetle, *Chilocorus nigritus*. 13. Larva. 14. Pupa in skin of last larval instar. 15. Adult beetle.

beetle has not been found in the coffee districts of Mysore, in the Shevaroys it is reported to be a very efficient check during the colder months. Attempts to introduce this species into the coffee districts of Mysore will be made.

A minute tick about the size of the young of green

bug, but easily distinguishable from it by its faster movements, is responsible for the destruction of a number of nymphs while they remain beneath the mother (see Plate IV, Fig. 2). These ticks are disturbed when the mother bug is lifted off and can then be seen running about. Their reproductive powers are great, but the numbers vary greatly with the locality and the season.

The larva of a cecidomyid fly was once detected amidst the young beneath a bug, but it has not been found again.

Fungus Enemies of Green Bug.

The most important checks to this pest belong to the vegetable kingdom. They are two fungi which under favourable weather conditions attack and kill off very large numbers of the pest. These fungi are two in number, one form giving a whitish appearance to the attacked bugs and hence called the white fungus, the other form producing a dark grey or almost a black appearance and hence known as the black fungus. This latter name is not a particularly fortunate one as it is likely to lead to the confusion of this fungus with the black sooty moulds which are found commonly on leaves attacked by scale insects and which are not in any way injurious to the insects themselves. The appearance of green bug when attacked by the white and grey fungus is clearly shown in plate I, Figs. 8 and 9. Frontispiece, Figs. 5 and 6, shows the appearance of bugs attacked by these fungi on coffee leaves. As these fungi are at present under study and will be described fully in a separate publication, only a short account of them will be given here.

The White Fungus (*Cephalosporium lecanii*, Zimm).—This fungus usually makes its appearance in coffee estates early in the South-West monsoon, and under normal conditions of rainfall spreads rapidly, killing off more than 90 per cent of the bugs. The presence of the fungus in a bug is to be made out first by its changing to a pale yellow colour. Soon the fungus begins to break out as fine white threads on the surface of the bug. These threads gradually grow to form a matted white felt over the whole surface and extending out on to the surface of the leaf (see Plate IV, Fig. 3). Minute spores are formed on certain of these threads, and it is these spores which,

when carried off by the rain and wind, lead to the infection of healthy bugs. It is obvious that as the infection of this pest depends in nature upon the chance dispersal of spores, every effort should be made to assist nature by producing the most favourable conditions for spread and infection. This subject will be discussed in detail when dealing with combative measures.

The Grey or *Black Fungus* (*Empusa lecanii*, Zimm.).—The grey fungus is usually not noticeable in coffee estates during the South-West monsoon. However, during the lighter North-East monsoon and throughout the early part of the cold weather, it is commonly to be found attacking green bug. Under favourable circumstances it may be found active even up to May, and when this occurs it furnishes a most efficient check to the increase of the pest. The fact that it occurs chiefly during the drier portion of the year has led planters to speak of it as the dry weather fungus. This is hardly correct as it also requires a certain amount of moisture in the air to develop and spread. However, it can undoubtedly grow under much less moist conditions than can the white fungus. The early stages of attack are shown by a whitish discolouration of the bug, but later this changes to a dark grey, while a greyish growth of fungus hyphæ appears on the surface of the bug. Some of these hyphæ produce oval or egg-shaped spores at their apices and by a mechanism characteristic of the group to which this fungus belongs, these spores can be shot off to distances of one or two inches. This fungus is therefore not so dependent upon wind and rain for dispersal as is the white fungus, and this undoubtedly accounts partly for its ability to spread during drier seasons of the year. If the body of a bug attacked by this fungus is cut open, a mass of dark brown spherical bodies are to be found inside. These are probably spores of a more or less drought-resisting character which help the fungus to tide over periods of drought. It is interesting to note here that in Java, where both of these fungi have been found, the white fungus appears to be just as effective as it is in Mysore. On the other hand, the grey fungus is looked upon as of minor importance occurring sporadically. On many estates in Mysore, on the other hand, the grey fungus is looked upon as a more effective check than is the white one. What has been said above with regard to the artificial spread of the white fungus applies equally to this fungus also.

Methods of Spread.

As already noted, the young, after hatching, generally do not fix themselves immediately, but wander about for some time. The movements are very slow and progress varies with the kind of surface. On the under side of leaves the movement is quickest. On loose, fine soil it is much slower, and still more so on moist soil. The following table gives an idea of the rate of progress of newly-hatched nymphs on various surfaces:—

Date	Time taken by the nymph to walk over the distance	Distance gone over	Condition of the surface over which the bug travelled	Remarks
19th March, 1917.	2 hours (11-30 A.M. to 1-30 P.M.)	16½ inches ...	Black glazed paper.	
16th March, 1917.	2 hours (1 P.M. to 3 P.M.)	11 ,, ...	Black sand paper	
21st March, 1917.	2 hours (11-15 A.M. to 1-15 P.M.)	7 ,, ...	Ordinary paper smeared over with fine mud and dried.	The nymph stopped for five minutes in one place.
23rd March, 1917.	2 hours (12 noon to 2 P.M.)	1½ ,, ...	Same as above but moist.	
21st April, 1917.	Do ...	30 ,, ...	Coffee leaf ...	Bug stopped now and then and had frequently to be forced to move on.

Young green bugs removed from leaves and kept in glass dishes, where they had no opportunity of feeding, were found not to live longer than four days. Under more natural conditions, life without food may be longer, but even so it seems improbable that young bugs can move far enough of their own accord to contribute largely to the spread of the pest in coffee estates.

It has been recently proved[1] that winds blow the young scale insects from their host plants to distances up to 450 feet, the longest distance for which the experiment was tried. The older bugs also do not always remain fixed. The movements after moulting have already been mentioned, and there is additional inducement for movement when the leaves are overcrowded and nutrition becomes insufficient.

The disturbances so caused may be so great that a

[1] H. T. Quayle, Dispersion of Scale Insects by the Wind. Jour. Ec. Ent. Vol. I. p. 486.

whole branch may be deserted for another. Fallen leaves containing bugs are carried long distances by the wind and they may carry infection very far. The adults have been found to survive a burial of twenty days. This is amply long enough to allow their being swept away by the wind, either free or on leaves, to find a new plant and to become fixed upon it.

Where shade trees have become infected, either directly by green bugs crawling on to them or by the action of ants, the danger of spread of the pest by the wind becomes much greater.

The agency of human beings and animals is also important. Coolies moving about among infested plants may carry large numbers, more especially of the young bugs which have not yet fixed themselves, to uninfected areas either on their clothing or on their bodies. Birds and animals may also spread the pest.

Host Plants in Mysore.

There are only a few plants on which the new species has been so far found, *viz.*, Albizzia spp. Wrightia tinctoria, Aegle marmelos, Artocarpus integrifolia, Mangifera indica, Psidum guyava, Citrus spp., Ficus spp. and Eugenia jambolana.

The effect on host plants.—The method of feeding of the green bug has already been described. The attachment of the bug along veins is apparently for the purpose of allowing it to draw on the elaborated food material that passes downwards to the branches and trunk. Where there are several hundreds of bugs drawing away what ought to go to the formation of new wood, the plant naturally suffers. Growth is impeded. Fresh wood is not formed. Even more serious is the collapse of the conducting vessels which takes place on very badly infested plants. On plants in pots, the green bark has been found to shrink so suddenly that the bugs were unable to withdraw the proboscis and move elsewhere.

Plants so badly affected invariably die. This, however, has never been observed in the estates. The insects affect the crops more directly. When blossoms are attacked, and subsequently the berries, the latter are reduced in size and often thrown out of normal shape.

Even where this does not happen, there may be a reduction in the crop brought about by the reduced vitality of the plants.

The crowding of the bugs on the tender leaves, for which there is a marked preference, also affects the plant at one of its most vital parts. The indirect effect of the sooty mould that invariably grows on the honey dew covering the leaves, as has already been described, may be so serious as to cause the leaves to drop off, though it must be admitted that this rarely happens.

How far these serious effects are produced depends on the health and vigour of the plant and the conditions under which it is grown. Where a tree is weak from other causes, the further tax on its strength by the bug often proves fatal. But where it is healthy and vigorous, the effect is largely minimised. Thus we find a very much smaller effect on coffee estates in Mysore than on the experimental plants grown in Bangalore, where the conditions are much more unfavourable.

Influence of Climatic Conditions.

The pest is most to be feared in years when the North-East monsoon is scanty and a long period of dry weather succeeds it. This occurred in 1913 and 1914, with the result that the pest increased at an alarmingly rapid rate.

The course of the pest varies considerably through the seasons in Mysore. It is difficult to detect the pest in infected estates immediately after the South-West monsoon. With the advent of the dry weather the bugs apparently come out of the shelters in the ants' nests and begin to multiply. There is even then a considerable check on them imposed by the dark fungus which kills a large number during the last quarter of the year and continues to be effective till the hot season if the North-East monsoon is abundant and well distributed. When summer is fairly well advanced, this hindrance is withdrawn and the insects rapidly regain their hold on the plants. The pest is at its worst immediately before the South-West monsoon. When sufficient rains have been received, the white fungus works havoc among them and before the last rains of the South-West monsoon are over, usually more than 90 per cent of the bugs are

wiped out. There is thus in most estates a definite alternation of favourable and unfavourable seasons which, provided the rains are normal, gives no chance of continued multiplication and sustained injury.

Combative Measures.

In the earlier stages of infection in Mysore, when no more than a dozen estates were infected, two objects were kept steadily in view:—(1) to detect the source or sources of infection, (2) to stamp out the pest from the estates where it had appeared. The measures taken with regard to the first of these objects have already been described. With regard to the second, many planters took the heroic measure of cutting out and burning all the infested plants as originally advised by Lefroy[1]. Plants were cut down, the dry leaves on the ground were placed on them and the whole heap burnt on the spot. In some estates they were carried in gunny bags to a central place where the burning was done. The bag used was each time soaked in an insecticide before it was carried back to the estate, so that any bugs on the bag would be killed. Both these methods were found not to work satisfactorily. The movements among the infested plants and their handling during these operations could not be done without the constant danger of young bugs getting on to the coolies and thus being carried to uninfested portions of the estates. The less objectionable was the first method. Even this left much to be desired. The spraying of the plants in the infested patches and those around was soon found to be the combative method open to the least objection.

Detection of Infection.

The correct identification of the pest caused a good deal of difficulty at first, but planters soon became familiar with its characteristic features. Even when the bug is correctly identified, the detection of infection requires some skilled observation. But, for practical purposes, it is sufficient to look for plants which are blackened more or

[1] Loc. cit., page 13.

less by the sooty mould on the upper surfaces of the leaves. If any plant has this appearance, it is almost certain that the plant or the shade tree above is infected with scale insects of some sort. But this symptom is not found until the scales on the coffee or on the shade tree are fairly numerous. If this stage has not been reached, one has to look for ants constantly moving about in large numbers on the plants. If plants have a large number of ants on them there is almost certain to be some insect which yields honey dew. It may be a species of dark plant louse sometimes found crowded on the very tender twigs and leaves, but this insect is rare on coffee. The more likely insect is a scale, and, if it is found, the species can be determined with the help of the description given in the earlier part of the bulletin and by a comparison with the coloured figures given in the frontispiece.

Spraying to Combat Green Bug.

When the infested patches are located, they should be marked conspicuously by long poles struck into the ground with white or red rags at the top. When this is not done there is often difficulty in finding the patches again. The plants should then be sprayed. In spraying, care should be taken that all the infested plants and those round them receive the solution in all parts, so that no bug escapes thorough wetting.

The insecticide at first used was a resin wash with soap. This was commonly prepared as follows:—

One pound of soda was dissolved in about one gallon of water in a 4-gallon kerosene tin. A pound of powdered resin was stirred in and boiled until the resin was dissolved and the mixture assumed the colour of coffee decoction. One pound of ordinary bar soap was added in shavings until it was also dissolved. Water was then added to fill the tin and the solution was allowed to cool, when it was ready for use.

The solution as thus prepared was by no means cheap. The price of one cwt. of resin was, at the time, (1912-1913) Rs. 14-8-0, one cwt. of soda cost Rs. 7 and one cwt. of Gossage's bar soap, about Rs. 20. Therefore the cost of the materials alone for 100 gallons of the mixture was roughly Rs. 9. The preparation of the mixture

was difficult and required supervision if the mixture was to be properly made. The correct proportions of the ingredients, and the order in which they were to be added, were some of the important details which could not be entrusted to coolies. The mixture contained, as already stated, one pound of soda to a pound of each of the other ingredients. It was soon found that this quantity of soda was excessive and could be reduced safely to eight ounces. As a matter of fact, this is the quantity usually given in formulæ for the preparation of resin washes. With the introduction of soda ash (anhydrous sodium carbonate) this quantity could be reduced to four ounces. The excessive quantity of soda originally used served no useful purpose. On the other hand, experiments conducted by the Department showed that a spray mixture with this quantity of soda had a very much more markedly scorching effect on the leaves than had mixtures with a smaller quantity of soda.

To avoid the difficulties enumerated above and to reduce the cost, it was suggested to Mr. A. K. Menon, the Oil Chemist and Soap Expert of the Madras Fisheries Bureau, that a new insecticide should be made out of the fish oil manufactured in large quantities on the west coast. He had considerable experience of the preparation of soaps while in England and was engaged in experimental work at the Tata Research Institute at the time. Mr. Menon readily took up the suggestion, more especially as this promised to provide a means of disposal of the oil for which there was, at the time, no profitable market. A new soap was made from fish oil to which resin was added according to the formula given. The mixture thus obtained could be easily dissolved in cold water and sprayed. The first samples of the new insecticide and the soaps were taken to one of the estates near Chikkenhalli and experiments on spraying were conducted by the junior author early in 1914. The following is a summary of the report of experiments conducted by him from 1st May to 7th of June, 1914:—

1. "Four different strengths of the emulsion were tried.

(*a*) 1 lb. of the insecticide per kerosene tin (4 gals.)
(*b*) 2 lbs. ,, ,,
(*c*) 3 lbs. ,, ,,
(*d*) 4 lbs. ,, ,,

Solutions (*a*), (*b*) and (*c*) were sprayed on to 28 trees, each of the trees being in two rows separated by intervals of two rows which were unsprayed. Solution (*d*) was sprayed on 7 trees only as it was feared it might injure the leaves seriously. On the same day the ordinary resin wash was also sprayed on 96 trees.

Effect on Plants.—All the trees were in blossom and the open flowers were badly scorched. The petals were blackened in patches and the tips of the stigmatic surfaces were also discoloured. The worst effect was produced by the ordinary resin wash which blackened the leaf tips also to a considerable extent before two days had elapsed. The leaf tips were hardly affected by the new insecticide. After about five days a very narrow margin was found blackened in the case of solutions (*b*), (*c*) and (*d*). On the whole the scorching effect of the new insecticide was negligible.

Effect on the Bugs.—Survivors were left in all cases, either young underneath which had not been touched by the spray, or adults themselves. The smallest number was found on trees sprayed with solution (*d*), (4 lbs. to one tin). With regard to solutions (*b*) and (*c*), there was very little appreciable difference between them or between them and the ordinary wash except that, in the latter case, the scorching was greater. A 2 lbs. to the tin solution will, if spraying is done carefully, prove as effective as a 3 lbs. to the tin solution or the ordinary resin wash.

Mixtures (*b*) and (*c*) were tried again on thirty trees in three rows each and the ordinary resin wash was also sprayed similarly, the trees in the central row were examined after an interval of a week and the result was again found to be practically the same.

Fish oil soap was also compared with ordinary bar soap in the usual resin soap mixture. Of the two mixtures tried, the one containing the fish oil soap proved superior to that containing the latter. There was a greater percentage of deaths, as the mixture had greater penetrating power. In all cases the trees sprayed had the smell of fish oil about them, for a few days after they were sprayed."

The new insecticide having been found effective, it was recommended to planters. It at once became popular and replaced the ordinary wash on practically all estates in Mysore and Coorg. During the first year about two

tons of it were sold through the Department alone and since then its use has become general in South India and Ceylon, wherever a cheap insecticide, easily prepared, is required to deal with sucking insects such as scale insects, mango hoppers, and plant lice.

Sprayers.—The most satisfactory sprayer to use is the Pressure Sprayer first introduced into South India by the Mysore Department of Agriculture. In this type after the charge has been poured into the sprayer, the air is pumped in until there is sufficient pressure to force out all the insecticide through the nozzle. Both hands are thus free, one to direct the spray and the other to turn the branches so that the spray can reach all the infested parts. In the other types of sprayers this is not possible as one hand is engaged continuously in pumping. The freedom of the second hand is of importance in spraying bushes with the spread of coffee and against insects which are on the under sides of the leaves and therefore not easily reached.

There are several types of pressure sprayers of which the one originally made by Gebrüder Holder has proved the most efficient. Since the outbreak of the war, sprayers practically identical with the Holder sprayers are being manufactured by a number of English firms, but unfortunately it has been almost impossible to get them out. These are sold in four sizes of one, two, three and four gallons capacity. A three-gallon sprayer is the most suitable for estate spraying. The price of these sprayers has risen very greatly since the beginning of the war.

Spraying.—The two most important considerations in spraying are, (1) that the spray should reach all the insects on the sprayed tree, and (2) that no solution should be wasted. To attain the first object, it is necessary that the insecticide should reach every part of the plant where the insects are found. Since most bugs are on the under surface of the leaves, the spray has to be directed from below. The top branches have to be lifted up or moved side ways to receive the full spray. The tender leaves and opening buds should receive special attention. Spraying should be done in the direction of the wind and never against it. When spraying is done against the wind, the spray fails to reach the places aimed at and a considerable quantity is wasted.

To prevent wastage of solution, in addition to the

precaution indicated above, the spray has to be made as fine as possible. A fine mist is all that is necessary to produce a thorough wetting of the leaves. When the spray is coarser, the solution soon begins to drip from the leaves and is wasted.

To get the maximum effect out of resin washes, it appears to be necessary to have the spraying done during the warmer hours of the day. It has been invariably our experience that spraying done during this period of the day is more effective than that done in the morning or evening.

The cost of spraying varies with the age and size of the trees, the number of trees per acre, the degree of infestation and the facilities that exist for spraying, such as the supply of water and labour. All these factors have to be taken into consideration, as they vary from locality to locality and from estate to estate. Therefore it is possible to give only approximate figures for the cost.

The number of plants per acre varies from 1,200 to 1,700. The amount of solution required for each plant depends on the age and spread of the tree. The labour required also increases with the age of the trees. In spraying young plants, on the other hand, there is likely to be a certain amount of wastage of the solution.

In the year 1914-15, 32,082 plants were sprayed under departmental supervision, with 2,890 gallons of the mixture or roughly with 13 cwt. of the fish oil resin soap. This works out at 11 trees per gallon. One pound of the spray soap would spray roughly:—

Plants of 9 years and older	15
,, 4 to 8 years	20
,, 1 to 3 ,, ...	25

The number of plants sprayed by one cooly in a day was found to be:—

75	for plants of 9 years and upwards
120	,, 4 to 8 years
200	,, 1 to 3 years

The number of plants per acre planted may be taken as 1,500 on an average.

On the basis of these figures the cost of spraying per acre is as shown on the next page:—

	Old plants 9 years and upwards			Medium sized plants 4 to 8 years old			Young plants 1 to 3 years old		
	Rs.	a.	p.	Rs.	a.	p.	Rs.	a.	p.
Chemicals ...	16	8	0	12	8	0	8	12	0
Labour ...	6	4	0	3	14	6	2	5	6
Total ...	22	12	0	16	6	6	11	1	6

It must be admitted that these figures are high, but the calculations are on the basis of fish oil resin soap at Rs. 18-4-0 a cwt., which was its cost when it was last obtained (in 1915). This is very high and should go down by at least Rs. 5 soon after normal conditions return. The price in 1913 and 1914 was Rs. 13 per cwt. It has also to be remembered that, at any rate in Mysore, it is not all the acres in an estate nor all the plants in an acre that are infested. Provided the spraying is commenced at the right time and the recommendations made in this bulletin are followed, the cost of spraying is not likely to be high at any time.

Brushing infested plants with the insecticide may be made quite as effective as spraying. In fact, if it is well done, it is even more effective, as in this operation the bugs are more or less dislodged or disturbed from their position and there is consequently a greater chance of penetrating beneath the bugs and reaching the young. But it cannot be regarded as anything more than a useful supplement. The controversy as regards the relative merits of spraying and brushing has arisen from a disregard of relevant considerations. Brushing is certainly out of the question as a practical measure when old bushy plants are badly infested.

On the other hand, when the pest is found only on a few of the more tender leaves and branches, spraying would entail a considerable wastage of the insecticide. As a general rule, spraying is advisable when the number of plants to be covered is large and the infestation is severe, and brushing when the infestation is light or the infested plants are young and few in number.

When to spray or brush.—It has already been stated that the pest is worst during the summer months (January to May) when its natural checks do not operate or operate

but feebly. The effectiveness of the two fungi depends on the abundance and normal distribution of the monsoons, the white fungus on the South-West and the so-called black fungus on the North-East.

Whether the South-West monsoon is abundant or scanty, little or no spraying can be done during those months on account of the great uncertainty of the weather immediately following the operation. The advisability of spraying during the last quarter of the year depends on the prevalence of the black fungus. If, as a result of the deficiency of the North-East monsoon, the fungus does not show up, spraying should be done once at least before the picking and, as far as possible, before survivors of the previous South-West monsoon have a chance to multiply. If, on the other hand, there appears to be a chance of the black fungus dealing effectively with the insects, the spraying should be deferred until after the picking season is over. It seems advisable that this spraying should be completed well before the beginning of the South-West monsoon. The survivors will then have a chance to multiply somewhat and afford sufficient material for the white fungus to travel rapidly over large areas and effect the destruction of the pest. The white fungus spreads somewhat slowly and too great an interruption in the continuity of infected plants, such as might result from spraying immediately before the monsoon, may prove a further hindrance to its spread, in which case it would be necessary to spread the fungus artificially.

These recommendations are with reference to estates where the infestation is wide-spread and past the chance of stamping it out. With regard to others where infection is only on a few plants or in a few patches, no limit can be set to the number of sprayings. In all cases whether the bug can be stamped out of the estate or not, it is of supreme importance that the bug should be looked for and dealt with immediately the South-West monsoon is over, in all likely places such as in the nests of ants and on tender leaves and opening buds.

Among measures other than spraying and brushing, the systematic destruction of the nest of ants, whose responsibility for the spread and increase of green bug has now been placed beyond a doubt, is of the greatest importance. An equally important measure is to increase the efficiency of the two fungi. To introduce them to

estates or parts of estates where they are not present, branches containing bugs killed by them should be cut and tied on to trees on which they do not occur. Cultures of the white fungus made in the departmental laboratory have been dissolved in water and then sprayed on plants in different parts of the estates and the infection has been successfully introduced. Such a measure will not be necessary in most cases as there are very few estates attacked by green bug, from which this fungus is entirely absent.

To furnish favourable conditions for these fungi, it appears necessary to increase and conserve the moisture in the air as far as possible. Both the fungi require a certain amount of humidity though they vary in this regard. While, in Mysore, the white form is regular and wide-spread and requires little attention beyond what has been recommended above, the black form appears to be more sensitive to variations in humidity. In the same estate, while it is present on trees under thick shade, a few feet away, in more open situations it will not be found. So, too, a slight failure in the North-East monsoon all but prevents its appearance. The fungus appears at a critical time when the bugs are reviving after the destruction caused by the white fungus during the South-West monsoon and its ability to keep them in check depends on a sufficiency of moisture. It might be possible by so regulating and improving the shade and by the prevention of too rapid evaporation to produce more favourable conditions for this fungus. The recommendation applies especially to those estates which are unfavourably situated with regard to the North-East monsoon or where shade and slope are such as to facilitate rapid evaporation. In these estates the replacement of such trees as silver oaks by those yielding greater shade might possibly diminish the virulence of the pest by increasing the efficiency of the fungi. Whether it is possible to regulate the shade so as to offer favourable conditions for the development of the black fungus and at the same time not to affect seriously the yield of coffee, is a question well worth the consideration of those planters who have been seriously troubled with the pest.

Future Prospects of the Pest.

The study of the green bug in Mysore has now reached a stage when a forecast of its possible course in the State may be hazarded with some justification. It was impossible to do it when the pest first appeared, as the experience in other parts of the world was too varied to predict with any degree of certainty its reaction to its new environment. The condition of coffee cultivation differs greatly in various parts of the world. It is grown at high elevations and at low, near the sea and away from it, in the open and under shade and there is a considerable variation in the cultural methods employed. The virulence of the pest has varied with these conditions.

The pest itself has exhibited an almost unique adaptability. As has already been shown, the popular name, green bug, now stands for a number of distinct species which are no longer true to the original description of Green and which may have been produced as a result of different environments. With the diversity in the natural conditions under which coffee is grown and in the methods of cultivation on the one hand and with the great adaptability of the scale on the other, it is impossible to predict what the course of the pest may be in any new area attacked.

The sinister reputation of green bug is largely due to its history in Ceylon. It is, therefore, necessary to understand precisely the share the scale had in the destruction of coffee in that island. The collapse of the industry was due to several factors of which the scale was only one. In his article on Coffee Leaf Disease, the Rev. R. Abbey[1] wrote, "The present year (1878) is the most disappointing the coffee industry has known, the average yield according to Ceylon statistics being below 2 cwt. per acre." He gives figures which show a progressive decrease in the yield of coffee per acre from 4·28 in the triennium ending with 1868 to 2·98 cwt. per acre in the one ending with 1877. He states that the reduction in the yield was directly due to the leaf disease but may be

[1] Observations on Hemileia vastatrix, the so-called Coffee Leaf Disease, by the Rev. R. Abbey, M.A., F.G.S., Fellow of Wadham College, Oxford, Journal Linnean Society, December, 1878; cited from Observations on the Natural History of the Enemies of the Coffee Tree in Ceylon, by J. Neitner, revised by S. Green.

traced further to surface denudation of the soil against which the local methods of cultivation had provided no safeguard and which weakened the coffee tree considerably.

Some idea of the extent to which the soil denudation took place can be obtained from the description of some of the old trees of Ceylon estates given by a planter in his pamphlet on "Ceylon in the Forties and the Eighties." He says, "It must be admitted that well-preserved soil is not characteristic of every old estate in Ceylon. Nothing is more common than to hear the words 'the estate was washed out and worn out years ago,' by old planters when describing such estates. In selecting abandoned coffee estates for tea, experience alone can discriminate between the good and the bad. In some old places every trace of the original surface soil has disappeared, the roots of the coffee tree standing a foot or more in the air above the present level."

As a result of these causes a marked preference for tea cultivation had already set in among the planters before green bug appeared. The following figures from the pamphlet quoted, clearly point to this fact :—

Quantity of tea shipped from Ceylon during the five years 1880-1884 :—

	lb		
1880	114,845	from 13 estates.	
1881	311,145	,, 15 ,,	
1882	621,068	,, 56 ,,	The year in which green bug appeared.
1883	1,599,687	,, 111 ,,	
1884	2,225,294	,, 135 ,,	

These facts establish clearly that green bug was responsible only for the rapid abandonment of what was fast becoming an unprofitable industry. What the actual effect of the bug on coffee, without the aid of contributory factors, would have been, it is difficult to say, though it seems probable that, under the conditions of rainfall and methods of cultivation which prevailed in Ceylon, the destruction of coffee would have been only a question of time.

The conditions of South India are different. The rainfall is less evenly distributed over the whole year, being concentrated in certain definite seasons when the precipitation is sufficiently abundant for the vigorous growth and spread of the fungi. Coffee is grown under shade, and surface denudation and evaporation is prevented

by the heavy mulch of leaves. Even with these advantages, the course of the pest has been erratic. On the Pulneys several estates have had to be abandoned. On the Anamalais, while coffee has suffered little on one slope, on the other it has been badly attacked. On the Shevaroys, above 4,000 feet, there are estates where the coffee borer (*Xylotrechus quadripes*) is looked upon as far more serious than green bug, while on the Nilgiris constant attention appears to be necessary to prevent the bug from getting out of hand. In the Wynaad it has not been taken seriously at all. In Mysore the outbreak in the coffee districts took place after several years of deficient rainfall, when the immediate danger of further drought had by no means disappeared. The two years that followed the infestation were dry years and would have been sufficient for serious injury, if vigorous measures had not been taken immediately. With the return of more normal rainfall, the efficiency of the two fungi has considerably increased, so that, while the necessity for spraying and other remedial measures has not disappeared, no serious injury need be apprehended, provided the continuity of the bug multiplication is year after year interrupted by the visitation of its vegetable parasites. If this varied behaviour of the pest is any guide, it would seem that coffee does not stand in serious danger in those localities in South India where the South-West monsoon is abundant or is followed by a liberal precipitation in the North-East monsoon, so that both the fungi are effective and the multiplication of the bug is restricted practically to the summer season.

Summary.

Green bug was almost certainly introduced into the coffee estates in Mysore from Bangalore.

It is spread by the agency of wind, fallen leaves, birds, ants, higher animals and human beings.

Green bug is variable in its behaviour and virulence.

The term "green bug" now stands for a number of distinct species, of which the Mysore form is one.

The Mysore form (*C. colemani*) has larger reproductive powers than the Ceylon form (*C. viridis*).

There are two fungi which act as very effective checks to the multiplication of the pest in Mysore, provided the monsoons are regular and normal.

When and where the monsoons are deficient so that the fungi do not operate, or operate but feebly, it is especially recommended to adopt the remedial measures enumerated.

(1) Spraying and brushing are the best artificial methods of keeping the pest under control. The best insecticide found up to the present is the fish oil resin soap prepared and sold by the Madras Fisheries Department, and the best type of sprayer is a pressure sprayer.

The insecticide should be used at the rate of one pound to two gallons of water. The cost of spraying will be, on an average, about Rs. 17 per acre.

(2) All nests of ants should be systematically destroyed.

(3) The fungi should be spread over the estate immediately after their appearance by tying up branches containing them to trees which do not show them.

(4) The efficiency of these should be increased by proper selection of shade trees and the regulation of the shade and by preventing rapid surface evaporation in young coffee through the agency of a cover crop.

THE BROWN BUG.

SAISSETIA HEMISPHÆRICUM, (TARG.) FERNALD.

Mrs. Fernald, Catalogue of the Coccidæ of the World. Hatch Experiment Station. Bull. No. 88, 1903.

LECANIUM HEMISPHÆRICUM, (TARG).

E. E. Green, Coccidæ of Ceylon, 1896-1908, p. 232-33. Indian Museum Notes, Vol. I, p. 113, 1889-91.

H. M. Lefroy, The More Important Insects Injurious to Indian Agriculture. Department of Agriculture in India, Vol. I, No. 2, 1907, p. 247.

George Watt, The Pests and Blights of the Tea Plant, 1888, p. 330.

Lefroy, Insect Pests of Coffee. Department of Agriculture in India. Bull. No. 2, 1903, p. 12.

Unlike green bug, the brown bug on coffee has for long been known in all parts of South India as a more or less serious pest of coffee. It is of universal occurrence in the tropics, where it thrives on a very large number of plants both cultivated and uncultivated. In temperate regions it has been recorded on several plants such as palms and orchids grown in green houses. The earliest record of its occurrence on coffee is from Ceylon where, according to Nietner, it appears to have been in existence from a very early period, but attracted attention only in 1845, when its rapid spread over several estates caused considerable alarm to the planters. It continued to be the cause of much anxiety until the fifties, when it began to decline and lose its hold. Nietner wrote in 1872, "I may add that now there is not nearly as much said about the bug as fifteen or twenty years ago, and although we shall never get free from it, it is to be hoped we shall gradually hear less and less of it." Green[1] writes in 1896 that Nietner's prediction came true and for some years before coffee failed, the bug, as a pest, had practically disappeared. On tea, which has replaced coffee in Ceylon, the pest has succeeded in asserting itself only on individual bushes and never on any considerable area.

[1] Green. Coccidæ of Ceylon, p. 234.

In India, the first record appears to have been published in the Indian Museum Notes for 1896, in an account of Scale Insects Collected in Madras in 1892-93. About the same time, Watt recorded it on tea in Assam. It is highly probable that the insect was in existence in India at a much earlier date.

Status as a Pest.

Though long known, the brown bug has not been looked upon as a serious pest of the more important crops at any time in India. Mann, in describing the relation of brown bug to tea in North India, points out that the pest usually occurs in sheltered positions and that the damage done by it has been light. It is more often found on the young woody twigs of the tea less than one year old but also on the underside of the leaves. The damage hitherto attributed to this insect is small. In South India it stands in much the same position. In relation to tea, Green says, "It causes some injury to individual bushes but usually confines its attacks to plants that are sheltered from rain by over-hanging rocks."

With reference to brown bug as a pest of coffee in South India, Lefroy writes, "The bug infects the coffee plant to so great an extent that the sap of the plant is drained away and the plant dies." The description is apparently of individual bushes and sporadic outbreaks rather than of any permanent relation of the insect to the plant. The only serious and persistent outbreak which has come to the knowledge of the Department is on an estate where it has, in company with green bug, practically overrun the entire area and has defied all measures of control that have been used against it. Outside of this estate the bug has nowhere been found to attack more than a few plants at a time.

Description of Brown Bug.

The appearance of the insect has already been described in an earlier part of the bulletin.

The following is Green's description:—

Lecanium hemisphæricum (Targ).

Lec. hemisphæricum, Targioni-Tozzetti, Studi sulle Cocciniglie 1867, p. 27.
Lec. filicum, Boisduval.
Bog. coffeæ, Walker.
? Lec. anthurii, Boisduval.
? Lec. hibernaculorum, Boisduval.

Adult female, varying in colour from pale brownish-fulvous to deep chestnut brown ; all intermediate shades being represented often on a single plant. The paler forms are often marbled with brown. There is usually a darker sub-marginal zone, but this is not always apparent. The common form on tea and coffee is bright castaneous, with deep castaneous sub-marginal zone. Even with a hand lens the derm is seen to be closely specked with minute translucent cells. A few small raised waxy patches, arranged in more or less regular rows, on the median dorsal area. Form oval, hemispherical ; the margin usually outturned and slightly flattened, but often concealed by the bulging sides. In the early adult there is a distinct median longitudinal crest and two transverse ridges ; but these generally disappear during gestation, though traces of them sometimes remain, especially in starved examples. The dorsal surface is highly chitinous and polished. During gestation the ventral area shrinks upwards, until the scale forms simply a chitinous shell filled with innumerable pale pink eggs. At this time the inner marginal surface is dusted with white mealy powder, and where a scale has been detached from the plant, an oval white ring marks its former position. Antenna with eight joints, of which the third is always the tongest and eighth next longest, sixth and seventh always shortest, and equal ; first, second, fourth, and fifth sub-equal, sometimes one, somelimes another, slightly the longer : the fourth dilated at distal extremity and without any hairs. Leg with tarsus about two-thirds length of tibia. Signoret states that this section of Lecanium is distinguished from all others by a "true articulation in the tarsus." If by this he infers that there are two distinct tarsal joints, I have failed to observe them. There is a slight constriction at the middle of the tarsus ; but this is noticeable in many species. Scales of anal operculum irregularly triangular ; both inner and outer sides somewhat sinuous : outer side considerably longer than base. Anal ring with eight stout hairs. Stigmatic spines three median spine long and curved, more than three times length of other two. Marginal hairs numerous, long, distinctly dilated and fringed at apex. Sub-marginal tubercles, five to six on each side ; obscured in old examples. Dorsal area closely studded with numerous well-defined oval translucent cells each with a smaller concentric ring in a deep layer of the derm, and a minute central pore on the surface. The cells towards the margin sometimes appear larger, owing to a paler outer zone rendered conspicuous by the darker ground colour of the margin. The cells of the median area are actually rather larger than those of the margin. Derm of ventral area with numerous minute circular pores communicating with cylindrical ducts. Size very variable, even on the same plant. Length 2 to 3 mm. Breadth 1·25 to 2 mm.

The early stages of the female show a gradual progression from the elongate oval to the broadly oval ; the ridges becoming more marked

until the adult stage is reached when, after gestation, they become obliterated as the insect assumes its final hemispherical form. The colour of the early stages varies considerably. On the tea plant, the young larvæ are of a pale straw colour. After a time three diffused crimson transverse bands usually make their appearance. By their gradual extension they eventually cover the dorsal surface with the exception of the ridges which remain pale. On adiantum and other ferns, the crimson forms seldom occur, the immature insect remaining throughout of a pale ochreous colour. In other examples there may be a brownish or blackish suffusion, commencing in the form of transverse bands.

The male insect, in any stage, is at the present time extremely rare, though some forty years ago, when Nietner was investigating the life history of the brown coffee bug, it appears to have been quite common. I have myself found them only on a single occasion, on the under surface of the coffee leaf, in 1889. The drawings then made (and reproduced herewith) do not show as much detail as is required for accurate comparison with other species.

Male puparium colourless, glassy, transparent, divided into nine plates.

Adult male, minute, reddish, wings strongly iridescent, with crimson costal nervure. Antenna rather short, reaching to scutellum. Genital sheath long and slender. A pair of slender, white caudal filaments, equal to total length of body; and a pair of moderately long fleshy tubercles, exterior to the caudal filaments.

Habitat on leaves, twigs and branches of coffee, cinchona, tea, and innumerable other plants amongst which may be mentioned adiantum and other ferns, asparagus, gardenia, guava (Psidium guyava), cobæa, anthurium, loranthus, bamboo, etc. In fact the species may be considered as omnivorous as it is cosmopolitan. It has been recorded from almost every country in which coccidæ have been collected in both hemispheres.

There is one peculiarity in brown bug as it appears in Mysore which is not referred to in the above description. Along what Green calls the " inner marginal surface " there is sometimes more than white powder; there is a definite secretion of waxy filaments sufficiently abundant, in some, to project outwards and form a white fringe. This is apparently of the same kind as that found in the mealy bug (*Pulvinaria psidii*). The point is of some importance because it indicates that the characters on which the classification of coccids is based are, as Green remarks, " very relative and occur in all stages of modification."

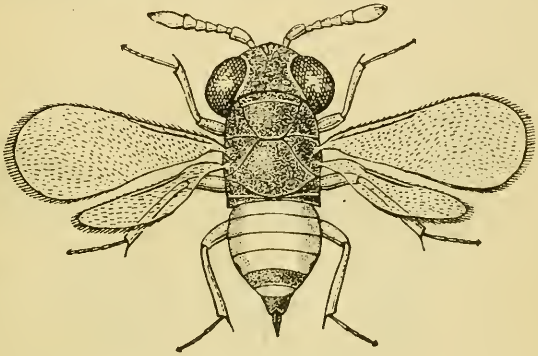
The life history of the pest follows much the same lines as that of green bug. The brown bug, however, lays eggs instead of bringing forth young. The process of moulting is the same in both the species. Both young and adult are less particular about the place of fixation. The period

of life of individual bugs has not been determined as it is impossible to say when they die. The total number of days from the time of hatching to the time when young come out, varies from 70 to about 83 days. The number of days during which young continue to come out from under the mother has been found to be about 16 in the case of a large bug which laid 684 eggs.

The following is the record of emergence from under a female brown bug in the insectary:—

1st day	78	5th day	28	9th day	56	13th day	21
2nd ,,	34	6th ,,	42	10th ,,	59	14th ,,	38
3rd ,,	31	7th ,,	57	11th ,,	62	15th ,,	9
4th ,,	58	8th ,,	39	12th ,,	64	16th ,,	10

The eggs are of a pale pink colour. The young nymphs when hatched are also pink in colour but of a deeper shade. After the first moult they turn yellow. In the subsequent



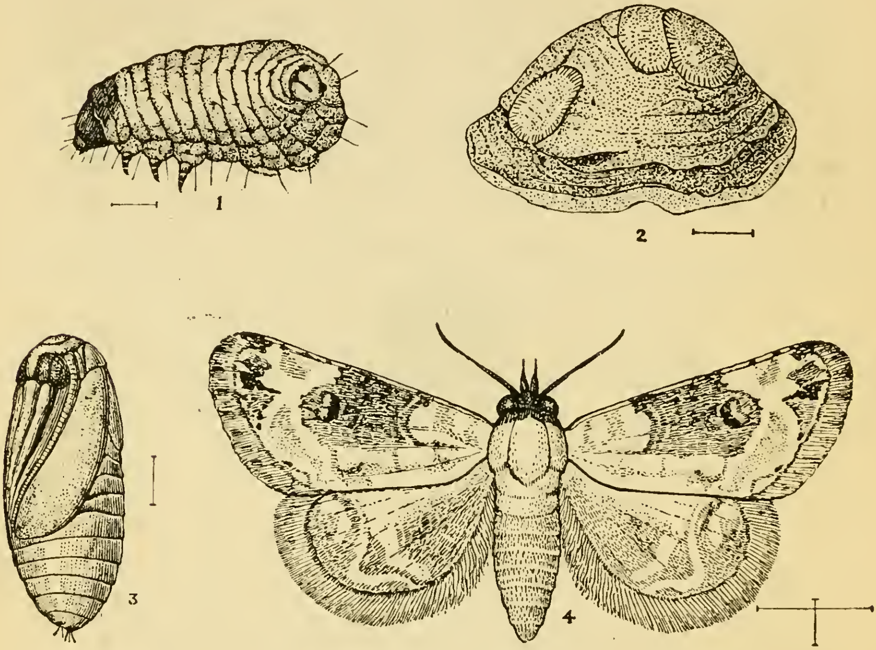
TEXT-FIGURE 16.

Hymenopterous parasite of brown bug.

instars there is a considerable variation. Some remain yellow until the adult stage is reached when the upper surface becomes marbled with black preparatory to changing to brown. Other nymphs are either crimson all over or have three or four more or less conspicuous broad crimson bands on a yellow ground colour. The uniformly crimson colour does not appear to be formed by the extension of the bands found in the banded forms. The bands may be narrow or broad, light or deep coloured and there may be no more than faint traces of them. In the later stages of the growth, these bands, instead of intensifying and running into one another, appear to become diffuse and faint. The marbling with black appears to arise in these

banded forms also but only in proportion to the amount of yellow present. The pink forms turn to brown without the previous admixture with dark colour. Egg laying may commence before the skin hardens and turns to brown. The honey dew secreted by brown bug is less liquid and the growth of sooty mould is not so conspicuous as is the case with green bug.

Male.—The male has been noticed in Mysore only once, in May 1915, but has not been studied.



TEXT-FIGURE 17.

Eublemma sp., a moth whose larva attacks brown bug and mealy bug. 1. Larva. 2. Case made of remains of scale insects under which larva lives. 3. Pupa. 4. Adult moth.

ENEMIES.

There are a number of hymenopterous parasites attacking brown bug. There is also a fly, the maggots of which feed on the eggs. The larva of a moth, *Eublemma* sp., also feed on the eggs and can be found with an oval shelter made of skeletons of brown and mealy bugs on its back. Text-figs. 16 and 17 and Plate IV, Fig. 1, illustrate a hymenopterous parasite and the moth *Eublemma* which have been found attacking this pest. None of these is an efficient check.

Treatment.

As a general rule no treatment appears to be required in Mysore. When individual trees or bushes are affected, the bug is thrown off apparently without causing serious injury. Large trees like sandal and shade trees appear to be able to survive even the worst attack. Where the pest threatens serious damage, spraying has to be done on the lines recommended for green bug. In only one case (the estate referred to above) has extensive spraying been necessary, and in this case both green and brown bugs have obtained a more persistent hold than anywhere else in the State.

THE GREEN MEALY SCALE OR MEALY BUG.

PULVINARIA PSIDII (MASKELL).

E. E. Green, Remarks on Indian Scale Insects. Mem. Dep. Agri. 1908, Vol. II, No. 2, p. 32. Coccidæ of Ceylon, 1898-1903, p. 264.

H. M. Lefroy, Insect Pests of Coffee, pp. 3-9. Bull. No. 2, 1903, Dep. Agri., India.

This scale insect, popularly called mealy bug or the green mealy scale, is nearly as familiar and has practically as wide a distribution as brown bug. Mrs. Fernald records it from New Zealand, Hawaii, Formosa, Ceylon, China, Japan and California. Since then it has been found in Australia, Samoa, Seychelles, Philippine Islands and a number of other countries in or near the tropics. The insect is as omnivorous as it is cosmopolitan. Besides several garden plants as guava, mango, and citrus trees, it occurs on coffee, tea, cinchona, cardamom, species of ficus, canthium, teak, sandal, eugenia, garcinia and duranta.

The insect occurs throughout Southern India and must have been in existence many years before its record by Lefroy in 1903 from Mysore. Reference has already been made to the outbreak of this insect at Santaveri (Kadur District), which was mistaken for that of green bug (*Coccus viridis*). It is not possible to ascertain how severe this was. It seems probable, however, that the attention it attracted was due to the mistaken identity rather than the severity of the attack. In any case, no serious outbreak has come within the knowledge or observation of this Department since this record, although the bug is found throughout the State, in the plains as well as in the coffee-growing tracts. The characteristic appearance of the bug has already been described. The following is Green's more detailed description:—

PULVINARIA PSIDII (MASKELL).

Pulvinaria psidii, Mask. N.Z. Trans., Vol. XXV, p. 223 (1892.)

Adult female at first ovoid; moderately convex above: afterwards much shrivelled and contracted; elevated behind by the mass of eggs

and enveloping secretion. Colour green, more or less obscured by a white, powdery secretion; median area becoming brownish with age, the whole scale turning brown after death. Eyes black, conspicuous during life, anal operculum dark brown. After gestation, a mass of white cotton-like matter is secreted from the ventral area and pushed out from the margin. The insect then rests on a cottony cushion which projects on all sides, and is eventually re-curved over the margin. Ovisac profuse, highly convex, white, cottony, with an inconspicuous median furrow. Derm cells large, approximate, irregularly oval or circular; usually conspicuous in preparations from fresh material, but often very indistinct and difficult to demonstrate in old, dried material. Antennæ eight-jointed, third joint longest. Usual formula: 3, 2, (4, 5), (1, 8), 6, 7; but in some examples the fourth is markedly shorter than the fifth. Legs well-developed, tarsus about two-thirds length of tibia; foot with four digitules, the tarsals stout and dilated at extremity. Margin closely set with stout hairs, which are strongly dilated and dentate at extremity. Stigmatic cleft with three stout spines, of which the median is much the longest, curved and projecting beyond the margin. Valves of anal operculum variable in form and relative proportions of base and outer edge, but the base is usually the shorter. This variation is noticeable even in individuals from the same communities, and is particularly marked in some examples from myrtle, of which no two individuals were identical in this particular. Ano-genital ring with eight hairs, length of insect averaging 3 to 3·50 mm., but exceptionally large examples have reached 5 mm. Ovisac measuring 4·50 to 7 mm. in length. Some examples from myrtle, while showing all the structural characters of the type were exceptionally small, the adult insect measuring only 2 mm. in length with a correspondingly small ovisac.

Immature female more elongate, and with stigmatic indentations more marked. Sometimes mottled with olive-brown on discal area. In its earlier stages the insect bears a superficial resemblance to Lecanium viride, from which it may be distinguished by the absence of the dark intestinal loop.

Male unknown in Ceylon, though said to occur amongst examples from the Hawaiian Islands and elsewhere.

It is important to add to this description that the variability which Green noticed in Ceylon forms is much greater in Mysore, and affects not only the size and anal plates but also the antennal segments and the bi-lateral symmetry. The number of segments in the antennæ may be reduced from eight to as few as five and the abnormality may affect one side and not the other. There is also a considerable colour variation depending to some extent on the kind of host plant. Those on teak, for example, are almost invariably dark brown, while those on coffee are yellowish-green and approach closely to the colour of green bug. The newly-hatched young cannot be easily distinguished from that of green bug. In the succeeding

instars the bugs are more opaque than are the corresponding instars in green bug. The colour may vary from dark dull yellow to dark dirty brown. There are also from six to eight waxy protruberances along the median line which continue more or less to the adult stage. In some individuals, a dark brown oval object is found inside the body showing through the top skin. What the function of this is, is not clear. It has apparently no connection with the viscera. As soon as the bug is tense with eggs, it becomes more yellowish and shows for the first time the loop faintly. It becomes now restless, leaves the place of attachment and frequently moves about until it finds a suitable shelter as a fold of leaf and a crevice in the bark. Egg-laying takes place also in more exposed situations on the leaves themselves. The bugs do not seem to want any nourishment when the eggs are being laid as some transferred to glass dishes laid eggs, apparently unaffected by the change in condition. The life history is completed within two or three months. The newly-hatched young takes from fifty to seventy days to attain the adult stage. The secretion of meal and the laying of eggs is completed in about five days. It has not been possible to determine accurately the length of life of the insect owing to the difficulty of ascertaining the exact time of death.

The following table gives the number that crawled out from day to day from beneath four adult females:—

1st day	2	5	17	97	9th day	6	3	...	1
2nd ,,	11	2	14	96	10th ,,	4	1	2	...
3rd ,,	9	6	14	31	11th ,,	...	4	...	...
4th ,,	24	20	3	22	12th ,,	2	1	...	...
5th ,,	17	13	4	7	13th ,,	...	1	...	...
6th ,,	18	14	3	4	14th ,,	1	...	...	...
7th ,,	10	6	7	3	15th ,,	...	...	...	...
8th ,,	5	6	1	...					

Habits of the Insect.—The bug is not as partial to the sides of the veins as green bug. A large number may be found away from them or on top of them. There is, however, a decided preference for more tender twigs, especially those springing from the stumps of trees or branches cut off. On these, the bugs are usually found crowded. There is a plentiful secretion of honey dew. This is often so abundant as to cover the leaves not only of the attacked tree but also of those below and the resulting sooty mould may be sufficiently serious to cause the

dropping of the leaves. The injury to coffee is mainly due to this cause and not usually from the insect directly. The shade trees in Mysore, even when badly attacked, seem to be able to throw off the insect and survive. In any case, the apprehensions of serious injury which Lefroy appears to have had when he wrote the Insect Pests of Coffee seem to be groundless so far as Mysore is concerned.

Enemies.—There are but few enemies. Reference has already been made to the moth Eublemma whose larva feeds on both brown and mealy bugs. One hymenopterous parasite has been reared out. The egg masses are attacked by a fly whose maggots may occasionally be found in them. There are also two species of lady-birds whose larvæ feed on the egg masses. None of these occurs in sufficient numbers to act as an efficient check.

Remedial Measures.—The series of recommendations which Lefroy makes are based on assumptions which are no longer justified by the large experience of the pest now available. The insect has too wide a range of food plants to render practical the replacement of shade trees liable to attack by those which are immune. The isolation of unattacked shade trees and estates is also impracticable on account of the prevalence of the pest on almost every estate, nor is the pest so serious as to require these costly and elaborate precautions. As has already been remarked, the more serious loss is not from the death of the shade trees but the defoliation of coffee trees growing below them and this occurs only when the shade is dense and low. Under very tall trees, coffee is more secure, perhaps because the honey dew is more widely scattered in its fall and thus has no chance of concentrating on a few trees. The drier conditions under such shade also may have an influence. It should be possible, therefore, to reduce the sooty mould and consequent injury by thinning out the shade. As regards the shade trees themselves, in the rare event of these succumbing to the attack, they will have to be replaced by others, as spraying with a costly high pressure spraying apparatus is out of the question. On small plants, as garden plants, coffee, tea, the pest can be easily kept in check by spraying with a small sprayer on the lines recommended for green bug.

APPENDIX.

LIST OF COCCIDÆ FOUND IN PLACES WHERE MANURE CARTS STOP ON THEIR WAY TO OR FROM COFFEE ESTATES IN SAKLESPUR AND MUDGERE TALUKS.

Date	Place	Description of plan	Name of bug found	Name of the plant on which the bug was found	Remarks
16-9-13	Sankinahalli ...	From which manure carts going to coffee estates from Banavar halt.	Pulvinaria peidii ...	Euphorbia sp. ...	Mostly young
16-9-13	Do ...	Do do ...	Saissetia hemisphæricum	Unidentified ...	Small undersized specimens
16-9-13	Kenkinhalli ...	Near places where fodder is cut and sold to manure carts.	Do ...	Hedge plants ...	
17-9-13	Do ...	Do do ...	Ceroplastes cajanii ...	Cajanus indicus ...	
24-9-13	......	On Arsikere-Banavar road 108th mile where manure carts halt.	S. hemisphæricum ...	Unidentified ...	
26-9-13	Bindekeregollarthi	Where goat manure is stocked and carted to coffee estates.	P. psidii ...	Do ...	
Do	Do ...	Do do ...	Do ...	Canthium sp. ...	
14-9-13	Do ...	......	Ceroplastes cajani ...	Cajanus indicus ...	Female puparia full of eggs
30-9-13	Agoonda ...	Where goat and sheep manure is sold to coffee estates.	P. psidii ...	Ficus glomerata ...	Several specimens near egg laying
1-10-13	Honkumaranhalli	Where carts from Tiptur side halt ...	Do ...	Do ...	
29-9-13	Alkurgollarthi ...	Where goat and sheep manure is collected and sold to coffee estates.	Do and S. hemisphæricum.	Canthium sp. ...	Brown bugs nearly full grown
1-10 13	Balemana ...	On Arsikere-Channarayapatna road ...	P. psidii ...	E. jambolana ...	
5-10-13	Bommanihalli ...	Where manure carts halt	Do ...	......	Young and adult
Do	Metikurki ...	Do do ...	Aleurodids and P. psidii ...	Olea sp. ...	
Do	Do ...	Do do ...	Do ...	Bassia latifolia ...	
9-10-13	Medenhalli ...	Near Tiptur where manure carts halt...	P. psidii ...	......	
Do	Do ...	Do do ...	Aleurodids and P. psidii ...	......	
20-10-13	Katalli ...	Hassan District from which place carts go to Arsikere to cart manure.	Unidentified but not C. viridis	......	
Do	Do ...	Do do ...	Diaspis sp. ...	Loranthus ...	Plenty of males
Do	Sunkenhalli ...	Carts go from this place to cart manure to Saklespur and Mudgere.	Pulvinaria tomentosa ? ...	Jak ...	

EXPLANATION OF PLATES II TO IV.

PLATE II.

FIG. 1.—Photograph of typical green bug (*Coccus viridis*) from beneath, showing seven-jointed antennæ.

FIG. 2.—Photograph of green bug now found generally on coffee in South India (*Coccus colemani*) from beneath. Note the three-jointed antennæ.

FIG. 3.—Nymphal stage of (*Coccus colemani*) from beneath, showing three-jointed antennæ, mouth structures, legs and anal structures.

FIG. 4.—Photograph of mealy bug (*Pulvinaria psidii*) from beneath, showing eight-jointed antennæ.

PLATE III.

FIG. 1.—Photograph of coffee leaves and twigs infested with green bug (*Coccus colemani*).

FIG. 2.—Photograph of experimental infestation of coffee with green bug through the agency of an ant (*Oecophylla smaragdina*). The two coffee plants in pots have been isolated by standing them supported in basins of water. The plant to the left contains an ants' nest but was at the beginning of the experiment free from green bug. The plant to the right was badly infested. The only way plant No. 1 could be infested is by ants carrying the bugs across the tape joining the two plants. The crossing of the bugs of their own accord did not take place as the plants were under constant observation during the day and the connection was broken during the night.

PLATE IV.

FIG. 1.—Photograph of larvæ and pupæ of the moth *Eublemma sp.*, covered with empty skins of mealy bugs which have been destroyed by them.

FIG. 2.—Photograph of mite found attacking green bug.

FIG. 3.—Photograph of coffee leaf showing green bug attacked by white fungus (*Cephalosporium lecanii*).

FIG. 4.—Photograph of green bug showing at A the pupa of a hymenopterous parasite.

FIG. 5.—Photograph of green bug with hymenopterous parasite and hyper-parasite. A, the antenna of the parasite; B, the hyper-parasite; C, remains of abdominal portion of parasite.